ANNUAL REPORT

OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

1919

GEODETIC SURVEY
OF CANADA

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The supt.
Geodetic Survey
Ottawa

PRESENTED

WITH THE COMPLIMENTS OF

THE SUPERINTENDENT,

GEODETIC SURVEY OF CANADA,

OTTAWA.

DEPARTMENT OF THE INTERIOR, CANADA

HON. ARTHUR MEIGHEN, Minister — W. W. CORY, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL OGILVIE, Superintendent

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FOR THE

FISCAL YEAR ENDING MARCH 31, 1919

OTTAWA
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REPORT OF THE SUPERINTENDENT

OF THE

GEODETIC SURVEY OF CANADA

W. W. Cory, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

Sir,—I have the honour to submit, herewith, my Annual Report as Superintendent of the Geodetic Survey of Canada for the fiscal year ending March 31, 1919, together with summaries of the reports of the engineers in charge of various sections of our operations.

Review of Year's Operations

TRIANGULATION

Owing to the enlistment for overseas service of thirty per cent of the Geodetic Survey staff, together with the necessity for the strictest economy due to war-time conditions, much of the pre-war operations of the Survey has been discontinued during the war, and the activities of the Geodetic Survey of Canada during the past year have been confined to work of a strictly economic character, to operations identified with the progress of the war, and to co-operation of an international character with the United States Coast and Geodetic Survey.

War Service.—At the suggestion of the United States Coast and Geodetic Survey, a party was detailed for triangulation surveys on Passamaquoddy bay, on the Atlantic coast, along the international boundary between New Brunswick and Maine. The United States organization carried on a wire drag survey to make certain of these waters available as a naval base for allied fleets, and the Canadian party furnished the exact positions of numerous points and lighthouses to control the accuracy of this survey. A more detailed description of these operations appears on page 58.

International Co-operation in British Columbia.—In British Columbia there is another example of international geodetic co-operation. The engineers of the Geodetic Survey of Canada last season continued the projection of the primary triangulation along the British Columbia coast, which, when completed, will extend from Juan de Fuca strait to Dixon entrance. The United States Coast and Geodetic Survey having undertaken an extension of this work northward from Dixon Entrance to the head of Lynn canal, the Canadian surveys contemplate the continuation of the primary triangulation along the Yukon river to the point of crossing of the 141st meridian, which is the boundary between Yukon and Alaska. This work when completed and taken in conjunction with the extension contemplated by the United States Coast and Geodetic Survey in the vicinity of Tacoma, Washington, to the Canadian triangulation in the Juan de Fuca strait, will constitute a geodetic arc of over twenty-five degrees of latitude, and will connect Alaska, Yukon Territory, and British Columbia with the North American Datum, which was adopted by the Geodetic Survey of Canada in 1913.*

*See Annual Report of the Superintendent of the Geodetic Survey of Canada for 1918, page 31, for an explanation of the North American Datum.

It is to be pointed out that the value of these surveys in British Columbia, while very satisfactory from the point of international co-operation, and also from the scientific data secured, has its primary consequence in the control given for the accurate charting of the intricate waterways of the British Columbia coast by the Hydrographic Survey of the Department of Naval Service, and also as a basis for the mapping of cities such as Vancouver and Victoria, together with the continuation of the triangulation into the interior of the country along such waterways as the Fraser river.

Operations in New Brunswick and Nova Scotia.—To fulfil requests by the Militia Department for the geodetic control of their military maps in the vicinity of Halifax, the Geodetic Survey extended its triangulation from the bay of Fundy eastward towards Halifax. The reconnaissance for the selection of observing stations was completed during the summer of 1918 as far as Halifax, and part of the observing of the horizontal angles of the triangulation done. It is hoped that the necessary clear weather will be encountered during the summer of 1919 to enable all the necessary field work to be completed, in order that the needs of the Militia Department may be met.

A revision of previous reconnaissance surveys was also extended in the direction of Sydney, C.B., at the request of this same department to control the geographic position of their military mapping surveys.

The triangulation in the Halifax vicinity will also provide the exact positions of many church spires, lighthouses, buildings, etc., for controlling the accuracy of city mapping and for the charting operations of the Hydrographic Survey.

Detailed reports covering the activities of the various parties in Nova Scotia and New Brunswick will be found beginning page 55.

Triangulation along the lower St. Lawrence river.—On the lower St. Lawrence river one party was engaged on primary triangulation, determining at the same time the positions of lighthouses and church spires used by the Hydrographic Survey of the Department of the Naval Service in connection with the charting operations of the St. Lawrence river. It is to be regretted that lack of sufficient funds has for some years seriously handicapped the Geodetic Survey of Canada, so that it has not been able to keep *in advance* of the requirements of the Hydrographic Survey, but has generally come along after the hydrographic charting was completed. The result has been that much preliminary work has been necessary by the Hydrographic Survey which would not have been required had the Geodetic Survey been able to keep its operations in advance of those of the Hydrographic Survey.

Secondary Triangulation in Bay of Fundy region.—In the St. John, N.B., district the topographic division of the Geological Survey required a connection to the primary triangulation for controlling the geographic position of their St. John topographic sheet. This control had been temporarily supplied them by the geographic position of an astronomical station (latitude and longitude observed) supplied by the Dominion Observatory. This pier was tied in to our triangulation.

In the Moncton, N.B., vicinity the same requirements of the Geoloigcal Survey were met in a similar manner.

It is to be remarked also in connection with the St. John triangulation that the positions of numerous church spires, buildings and lighthouses, both in St. John and along the coast to Passamaquoddy bay were established by this same secondary scheme, thereby providing the accurate location of marks for the mapping of the City of St. John as well as for the charting of the coastal waters by the Hydrographic Survey of the Department of the Naval Service.

City Triangulation.—It has been mentioned above that the geographical position of points in the cities of Halifax, St. John, etc., are being secured by the

Geodetic Survey. It is believed that city triangulation is one of the important functions of this Survey, which in general may be stated as the supplying of points to control the geographic position and also the accuracy of topographic and hydrographic surveys throughout Canada.

In connection with the engineering problems of cities, one of the primary requisites is found to be accurate topographic maps of these cities and their vicinities. Such work as securing the accurate determination of the positions of points by means of triangulation, upon which to base more detailed surveys, also precise levels, is a class of work peculiar to the operations of the Geodetic Survey.

During the course of our surveys marked points are left where the demands for more control points for surveys by Departments of the Government, municipalities, etc., make the secondary development of our main scheme necessary from time to time.

Important direct public service results from the performance of city triangulation, and the probable extension of our main triangulation has been foreseen and allowed for in such cases. The data gathered in these cases are of direct benefit to the mappers of departments of the Dominion and Provincial Governments.

The most important example of this class of work to date is in the city of Montreal and vicinity, where a triangulation survey is in progress for the determination of the accurate position of points to control the accuracy of a topographic survey of the city of Montreal. The engineers of this Survey are closely co-operating with those of the city of Montreal in order that those points which will be of the greatest use for topographic mapping will be selected. The city of Montreal supplies all materials for the building of observing towers, signals, monuments etc.

PRECISE LEVELLING.

During the season precise levelling operations were carried on by three field parties—two in Western Canada and one in the provinces of Ontario and Quebec. Until 1918 the Geodetic Survey had only one line of precise levels across Manitoba and eastern Saskatchewan, this line paralleling the international boundary as far as Estevan and then turning northwest and passing through Regina and Saskatoon and on to Prince Albert. By the close of 1918 a duplicate line had been extended from Winnipeg by the most direct route, almost to Saskatoon. Only a shortage of funds prevented the completion of this line to close on the former levels at Saskatoon. Another line extending in a southwesterly direction from Yorkton to Regina was also included in the western field of operations.

In Quebec and eastern Ontario some connecting links were inserted in the level net, which was already fairly extensive and in the district between Peterboro and Toronto about 135 miles of levelling was added. A more detailed description of the season's operations will be found in the summary of the report of the Supervisor of Levelling.

The mileage of precise levelling from the inception of the work till the end of the season just closed, 1918, is distributed among the provinces as follows:—

	Miles.		Milles.
Ontario	3,517	Manitoba	882
Quebec	1,497	New Brunswick	864
British Columbia	1,385	Nova Scotia	705
Saskatchewan	1,266	Minnesota, U.S.A.	89
Alberta	1,185		

This amounts to 11,390 miles and is exclusive of 491 miles levelled in the Yukon in connection with the International Boundary Survey.

The total number of standard bench marks established since the beginning of the Survey is 3,312, which number does not include those bench marks of other organizations whose elevations have been determined by the Geodetic Survey.

Following out the previous custom a publication was prepared giving provisional results for some 1,492 miles of levelling and fixing the elevations of 495 permanent bench marks in the provinces of Quebec, Ontario and British Columbia. This publication became available for distribution in the month of October and was circulated widely amongst engineers and surveyors, universities, railway companies, libraries, and interested officials of the Dominion and Provincial Governments.

BASE LINES.

The only base line selected during the season of 1918 was near the northern end of Vancouver island for the control of the scale of the triangulation on the British Columbia coast. Owing to the difficulties of clearing the timber from this base, and the shortness of the season, the actual measurement was deferred until the summer of 1919. A short description of the conditions which were encountered will be seen on page 46.

ASTRONOMICAL WORK.

There is one source of error in triangulation systems which is called "twist." This error, as its name implies, is a gradual deflection of a scheme of triangulation from its true position due to certain unknown causes. In a triangulation system this twist is noticed, for example where the triangulation schemes along two meridians are joined by a cross line of triangulation along a parallel of latitude. In such a case it is often found that the systems along the meridians have approached or receded from one another by an amount which cannot be accounted for by the known errors of the triangulation. It will be seen that the measuring of a base line will not remove this error, as the measurement of a base merely controls the scale of our triangulation but not its lateral motion or "twist". Nor could astronomical observations control the positions of our end points, as they are subject to errors due to the deflection of the plumb line possibly many times the errors of either twist or scale.

Two Laplace points (longitude of a triangulation station and azimuth or direction to another station were observed) for correcting the "twist" of the triangulation were observed during the year. One at the head of the bay of Fundy near Amherst, N.S., was established to correct the bay of Fundy triangulation, the other on Vancouver island to straighten out the triangulation on the British Columbia coast.

It cannot be too strongly emphasized that the deviation of the plumb line, an effect which enters directly into all astronomical determinations of geographical positions, is not necessarily or generally small in value. Two astronomical points on the St. Lawrence, Tadoussac and Father Point, illustrate this clearly. At Tadoussac the vertical leans to the southeast by about 550 feet south and 500 feet east, while that at Father Point leans to the northwest by about 530 feet north and 690 feet west. Astronomical determinations would place Tadoussac 740 feet southeast and Father Point 870 feet northwest, respectively, from their geodetic positions, which would have been a most serious cause of error to the Hydrographic Survey of the Department of the Naval Service who quickly realized the importance of Geodetic Survey work, work free from the deviations of the plumb line.

This effect of twist in azimuth is removable from triangulation in the adjustment of errors by means of a simple relation, called Laplace's equation,

that exists between azimuths and longitudes,

$$\alpha_A - \alpha_G = -(\lambda_A - \lambda_G)\sin\varphi$$

where α_A and α_G are the astronomic and geodetic azimuths at a station (called a Laplace station)
and λ_A and λ_G are the astronomic and geodetic longitudes at a station, and
ϕ is the latitude of the station.

The discrepancy between the two sides of the above equation gives the twist in azimuth of a line of the triangulation system.

Laplace stations are introduced about two hundred miles apart in the triangulation system.

The report of the engineer in charge of the work begins on page (66.)

Mean Sea Level as the Datum for Elevations.

The datum which has been adopted for the precise levelling operations of the Geodetic Survey of Canada for elevations is Mean Sea Level. On account of the importance of this choice of datums, a short account of the method of its determination together with the reasons for its adoption will be of interest.

Mean Sea Level may be defined as the surface which the water of the ocean would assume were it not acted upon by the attraction of the sun and moon or disturbed by the wind.

The primary requisites for a proper determination of mean sea level are an automatic tide-guage and a permanent bench-mark, closely adjoining, to which the readings of the sea surface may be referred. Regarding the determination of sea level from one of these gauges, Dr. Dawson, Superintendent of the Tidal and Current Survey, Department of the Naval Service, has made the following statement:—"The value of mean sea level is found in the first place for a period of one continuous year at a time. It is based upon the height of the tide at every hour, day and night, taken from the autograph record of the tide gauge. By comparison with direction observations for time and height, the record from the registering gauge is reduced to a truly uniform datum from year to year, with relation to a bench-mark. The value of mean sea level in each year is thus the average of 8,760 individual measurements at successive hours without a break. If any serious interruption occurs, a fresh beginning is made."

Such an average will give a determination reliable to the third decimal of a foot. There is, however, a slight variation in the value of mean sea level from year to year, which may amount to 0·15 foot above or below the average. This is undoubtedly actual and not due to any want of accuracy in the observations. Good evidence of this may be had from a comparison of the year to year variation at New York and Halifax, two stations on the open water of the Atlantic coast. A single year's series of observations is thus not sufficient to furnish a datum for overland levelling of high precision, but an average of five years or more may be considered thoroughly trustworthy.

It is to be pointed out that the site selected for the tidal station must be on the *open* sea coast, in a locality not influenced by river or ocean currents and not so confined as to prevent free ingress and egress of the tide water. Having fixed the elevation above mean sea level of the fundamental bench mark adjacent to the tidal station, it becomes the function of precise levelling to carry this accurately determined datum to inland points.

In extending the system of precise levels throughout the United States, the assumption was made by the United States Coast and Geodetic Survey that the height of mean sea level was the same on the Atlantic coast, the Pacific coast, and the gulf of Mexico. The Great Trigonometrical Survey of India made a similar assumption, it being premised in each instance that the tidal stations were open-coast ones and that observations had been conducted

for a sufficient number of years. The precise levels were then adjusted to agree with the values furnished by the tidal observatories. The above procedure seems the only logical one to follow as any error that can remain in a well-determined value of mean sea level is less than the probable error in the precise levelling, if the tidal stations are more than one or two hundred miles apart. In Canada we are fortunate in already possessing a sufficient number of principal tidal stations on both the Atlantic and Pacific coasts to give effective control to the system of precise levels. These stations are maintained by the Tidal and Current Survey, Department of the Naval Service.

Turning from this phase of the subject to a consideration of the value of mean sea level as a datum for levelling throughout the country, one might say that the desirability of having one uniform datum to which all local levelling operations in every part of the country can be referred is almost self-evident. Mean sea level is such a datum and possesses the further advantage that it can be determined locally (with more or less accuracy) at any coastal point, thus enabling local levelling operations at such points to be built up on the desired datum without the necessity of carrying levels from a distant bench mark.

With the object of sounding the opinion of the engineering public on the question of a mean sea level datum for elevations, the United States Coast and Geodetic Survey, in December, 1916, sent letters to a large number of city and state engineers and chief engineers of railways all over the United States, asking for their views. The concensus of opinion was strongly in favour of the adoption of such a datum and its extension throughout the country by means of precise levelling by the Federal Government—such extension wherever possible to precede rather than follow the development of the country. It was further brought out that in many cases elevations in regions more or less remote from the coast, while supposedly on a sea level datum, were actually to all intents and purposes on an arbitrary datum because of the lack of any precise levelling in advance of the detailed levelling. The labour and cost of changing plans, profiles, bench mark elevations, etc., from an arbitrary to a mean sea datum was emphasized—by city engineers especially. Naturally, the longer the change is deferred, the greater will the difficulty become.

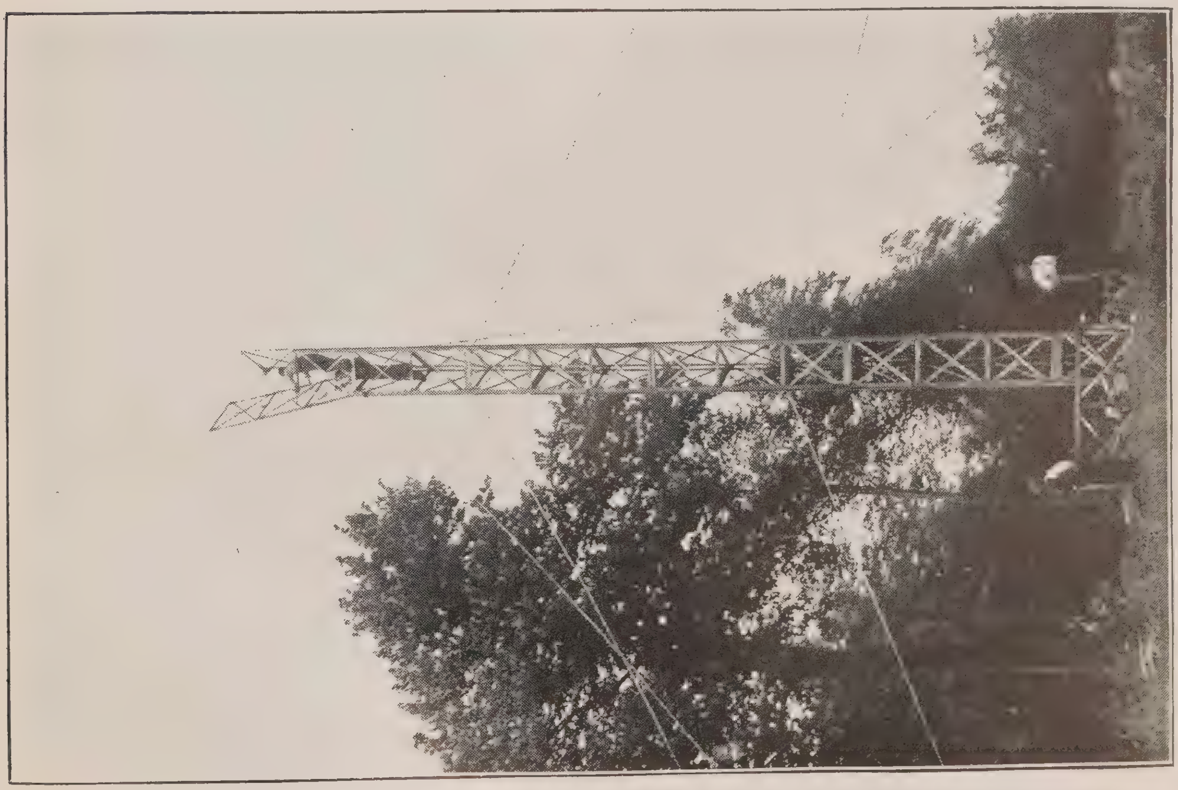
Triangulation Observing Towers.

To make triangulation stations intervisible it is often necessary to erect observing towers, on which to elevate the observer and his instrument. The height of these towers varies from 20 feet to 150 feet, depending on the topography and the nature of the obstacles to be overcome to secure this intervisibility of stations.

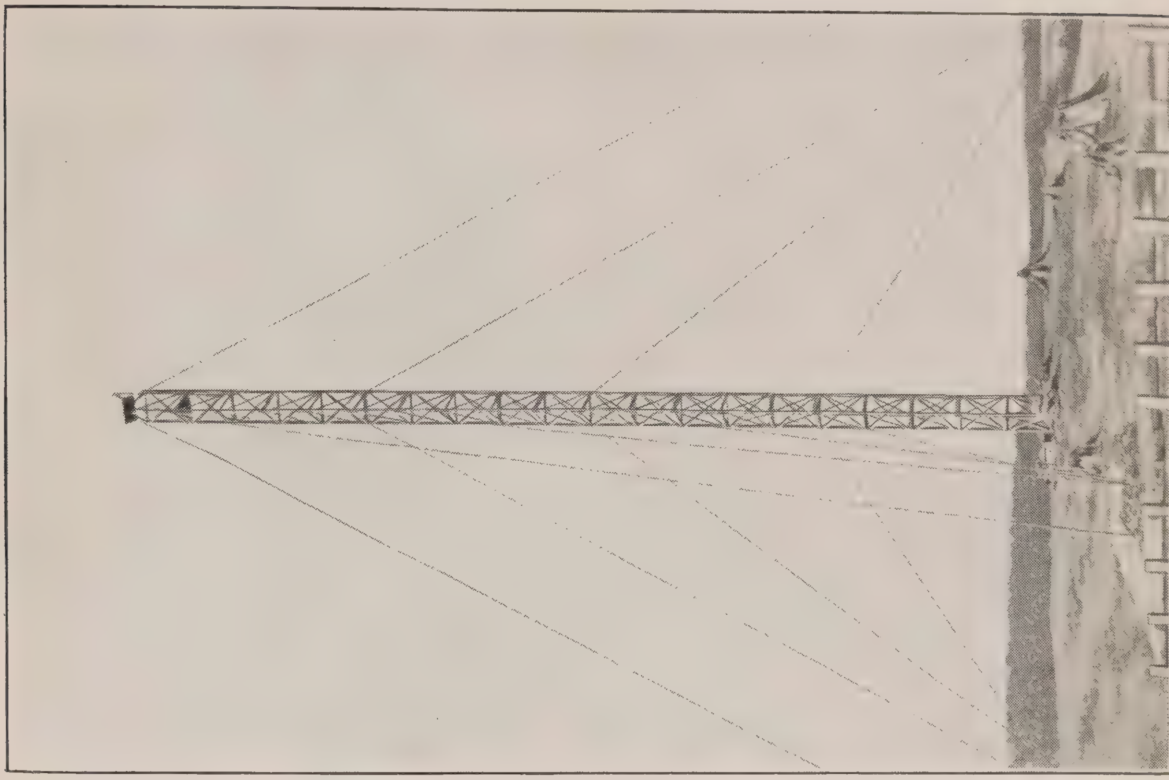
The triangulation stations are placed on the highest ground available, but often intervening hills or woods make it impossible to see from one station to the others from the ground, necessitating towers of various heights. Then again, local bush or buildings may require to be surmounted.

To determine the height of tower which is necessary at any station where only local timber or other obstructions are the factor to be overcome, is simply a matter of measuring the height of the obstruction above the ground at the station and building a tower to surmount it. Where the obstruction, however, is some miles away and cannot be seen from the ground at the triangulation station, as, for example, in the flat country of Southwestern Ontario, where there are many bush patches of high decideous timber, a portable reconnaissance tower of the type shown on page 11 has been used with success to determine the height of tower required.

This tower is triangular in cross-section and is composed of three- by twelve-foot panels bolted together as indicated in the illustration. The panels are staggered on three sides to provide sufficient strength, four-foot, eight-foot



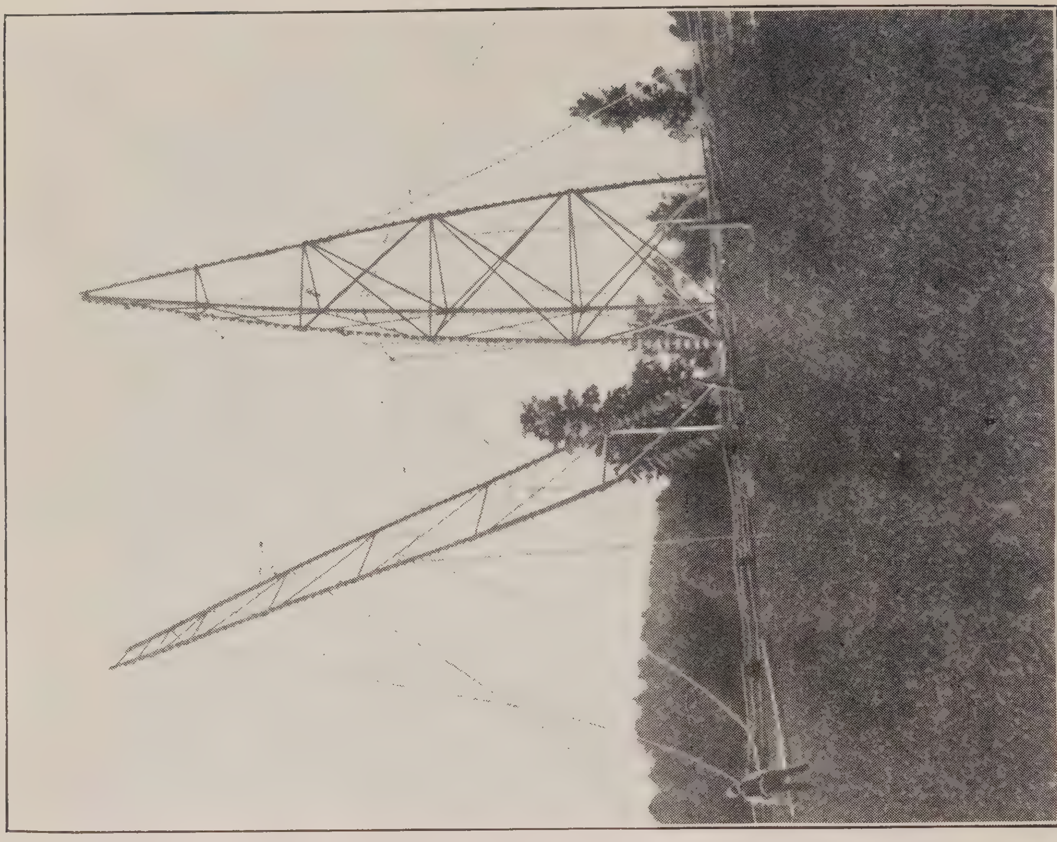
(a) In course of Erection.



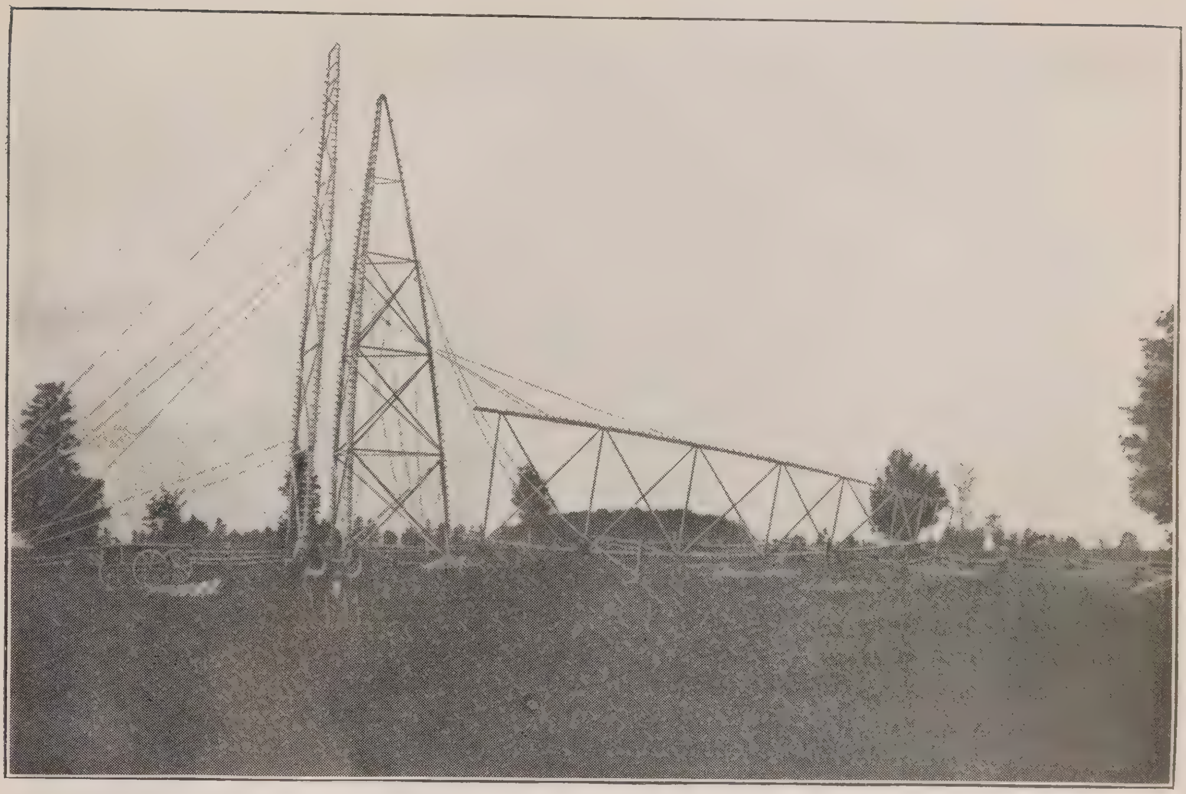
(b) Complete.

Portable Reconnaissance Tower.

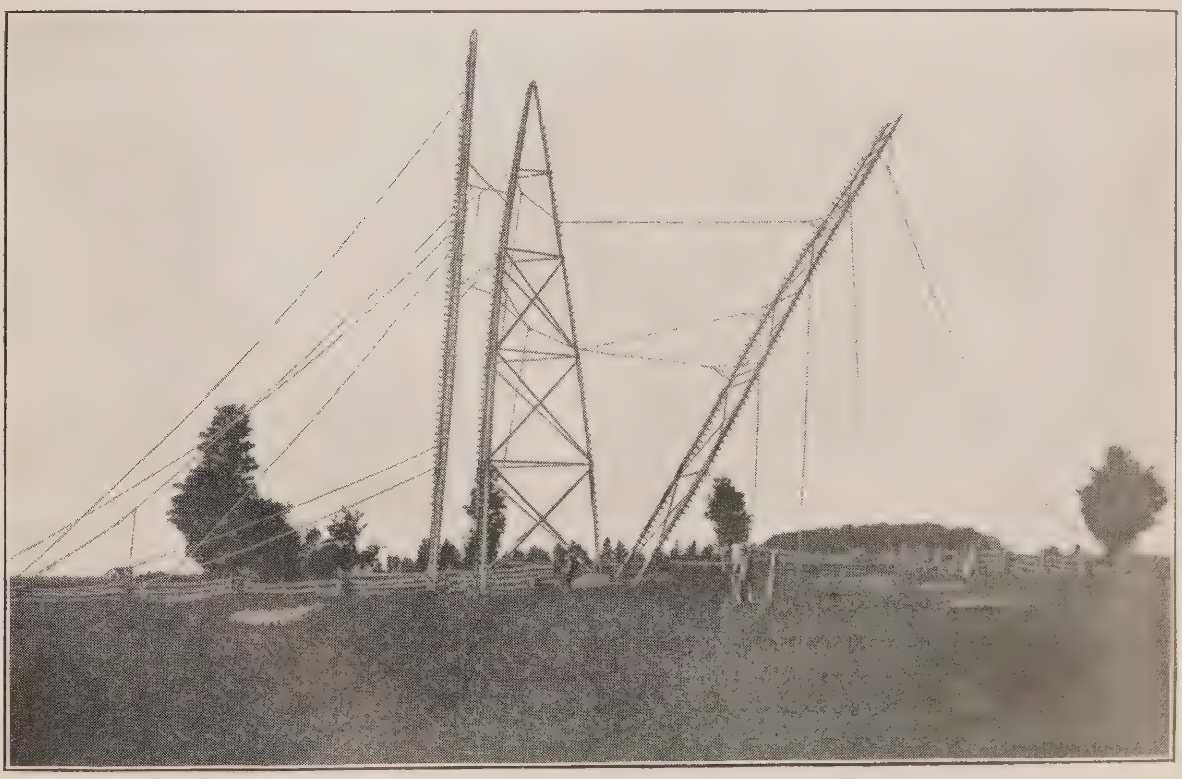
(a) Erection of Tripod of Triangulation Tower.



(b) Using tripod as a derrick to raise first side of scaffold.



(c) Turning side of scaffold on the ground before raising to get the braces underneath.



(d) Raising second side of scaffold.

and twelve-foot sections being used at the bottom and top of the tower. The time required to erect this tower by two or three men depends on the condition of the ground for attaching stay wires. On the average it can be erected in four or five hours.

The observing towers present outlines which are essentially different from any of the structures heretofore familiar to the public. There is no central shaft, and there are two structures—one within the other; also the outlines of these structures are curved instead of straight. The number and variety of questions that have been asked with reference to the reason for their sudden appearance are more easily imagined than answered. In one quiet hamlet they were supposed to mark concealed magazines for storing explosives; in another they were said to have been erected for the use of political orators with megaphones, that the ensuing general election might possess novel features, and incidentally tend to the glory and perpetuation of the Government of the day. During the war the explanations and conjectures were many and diverse.

These towers consist of a tripod, on top of which the instruments are mounted, surrounded by a scaffold, which at no place touches it and which holds the floors to support the observer. Thus, when a theodolite is mounted on top of the tripod, the observer may walk around his instrument without disturbing it.

The whole structure is designed and erected so as to obtain maximum rigidity with the minimum weight of timber, the latter varying in size from two-by-four to eight-by-eight inches, according to the height of the tower. By renewing the footings, tightening the spikes, and, if necessary, reinforcing the tripod legs, etc., the towers may be of use for a period of about ten years.

The construction of the towers is carried on by men especially adapted to the work. The tower building party consists of a chief of party, assistant, three to four men and a cook.

The manner of erecting the towers is fully illustrated by the photographs taken at the different stages of construction. One side of the tripod and two sides of the scaffold are framed on the ground. A single post is so placed that it can be used as a gin-pole for hoisting. With the aid of blocks and tackle the side of the tripod is raised from the ground by horse-power to an upright position; the third leg of the tripod is then raised and attached to the other two by ties and diagonals. The completed tripod is used to raise the two sides of the scaffold framed on the ground. After these sides are raised they are connected by ties and diagonals, thus completing the structure. This system is used for towers as high as eighty-seven feet. The sections above that height are raised from the ground by block and tackle and spiked into position.

The following table gives the number of feet board measure, in towers of different heights:—

—	Feet B.M.
102-foot tower	6,200
87 " "	4,600
77 " "	4,200
67 " "	3,300
47 " "	2,200

The time required for digging foot-holes, hauling timber, erecting the tower, loading the feet with rock, building the concrete reference monument at each tower, depends on the height of the tower, on the accessibility for hauling timber, on the weather, etc., and will generally occupy from six to twelve days.

The Use of Automobiles and Motor Trucks on the Geodetic Survey of Canada.

The experience of merchants, commercial travellers, manufacturers, civic officials, etc., points very conclusively to the economy of the use of motor trucks in place of horses, where much running around the country is necessary. It is hence only natural that engineers of the Geodetic Survey whose work carries them more particularly to the settled parts of the country, find the use of automobiles and motor trucks very economical in the matter of time and a great saving in actual money spent for transport, in those parts of the country which are served by good, or even only fair roads.

For reconnaissance surveys a light runabout with delivery box on the back amply serves the purpose, and the cost of the car is easily covered in one year by the amount of time saved, exclusive of the saving in livery and automobile hire.

For observing parties, whose camp equipment, instruments, tools, etc., weighs about $\frac{3}{4}$ ton, a light one-ton truck is very suitable. On this work speed in moving from one station to another is essential in order that the best use of good observing weather may be made. In many parts of the country where teams for hire are scarce and the prices high, the time lost and money spent in moving camp in one year would more than pay the cost and upkeep of a truck.

For tower-building parties a one-ton to three-ton truck is needed, depending on equipment necessary, which in turn, depends on the general size of towers to be built. Here again the great economy of motor trucks is demonstrated.

In this connection the experience of the United States Coast and Geodetic Survey is of interest.* ". . . On all of the primary triangulation and reconnaissance for primary triangulation done during the fiscal year 1917, motor trucks were used as the means of transportation. On account of the fact that money spent for labour is one of the heavy items of expense in this class of work, the use of the trucks is very economical in enabling the observers to utilize much of the time for observing which formerly was employed in moving by teams from station to station.

It will probably be only occasionally that horses and wagons can be used in the future on primary triangulation and reconnasisance to better advantage than trucks. With the increase of good roads throughout the country, the trucks will become more and more economical on geodetic work."

Elements of Map Making, Showing the Part Played by the Geodetic Survey.

The various ways in which the results of the Geodetic Survey are used in the process of map-making are perhaps too little understood and appreciated by the general public. At the same time to those people living in the vicinity of the triangulation stations the broad outlines and underlying principles become lost in the details of the somewhat complicated operations of the engineers of the Survey at each particular station.

For this reason a short non-technical sketch of the process of map-making is here given. In order to illustrate the whole process and hence show the connection between geodetic work and map and chart making this description must go beyond the scope of the geodetic survey and will attempt to show by illustration and text each step in the field and office detail until the map is completed and ready for distribution.

Scientific and technical terms are intentionally omitted wherever possible, but wherever used are printed in italics and explained. Many of the technical steps which only confuse the issue are purposely left out.

*Annual Report of the Superintendent of the United States Coast and Geodetic Survey for 1917, p. 100.

Commencement of the Survey.—The engineer who starts the survey, called the *reconnaissance engineer*, first finds out if any Geodetic Survey stations are in the vicinity of the country which is to be mapped. This is very important as the Geodetic Survey covers a great deal of the country with stations whose distance and direction from those in other parts are accurately known and, as a result, the maps of different parts of the country based on Geodetic Survey stations would accurately fit together where they join, with no overlaps or discrepancies. It may also be noted that the stations of the Geodetic Survey of Canada are accurately connected with those of the United States Coast and Geodetic Survey, so that all maps which have the Geodetic Survey stations as a basis are in their correct relation to all United States maps as well as Canadian.

Triangulation Signal used in Secondary Triangulation.

Subsidiary Triangulation based on a side of Primary Triangulation as a control for Topographical Surveys.—The *reconnaissance engineer* selects two convenient geodetic stations as the basis of his work. The exact distance apart of these two stations is known, also the *azimuth* (direction of the true north) at each station, together with the *latitude* (distance from the equator) and *longitude* (distance from a north and south line through Greenwich, England) of each of the stations.

This line serves as a base line from which to start the system of triangulation which is described below.* The plan on page 18 shows this base line.

Triangulation.—Off to one side of the base line a third station is established on a hill where it can be seen from the ends of the base. This station, with the two ends of the base, forms a triangle, the angles of which must be accurately measured with an instrument similar to that shown on page 21, Annual Report of the Superintendent of the Geodetic Survey of Canada, March 31, 1918. The three angles of this triangle are measured in order that we may have a check on the accuracy of the observations, since by geometry we know that the three angles of a triangle must equal two right angles (180 degrees).

Trigonometry teaches us that, when we know any three parts of a triangle, one of the parts being a side, (there are six parts, three sides and three angles) we may determine the other three parts. In our present case we have four parts, three angles and one side (the base line), which enables us to determine the lengths of the other two sides, that is the distances from our third station to the ends of the base line, with substantially the same accuracy as that with which the base was measured. Where the lines are long, the curvature of the earth enters into this determination.

We now have three lines whose lengths are known instead of the one base line, and may use these lines in the same way as our base line for getting other distances. Thus our triangulation system is laid out covering the whole area to be surveyed, the angles are measured and the distances from station to station calculated. Where these distances are short, (up to 6 or 8 miles) signals of the type shown on page 16 are placed over the stations and are used to sight on from other stations when measuring the angles. Where the lines are longer, acetylene or electric lamps placed at the stations are used in place of the signals and the observations are made at night. The lamps used are shown on page 28 of the Annual Report of the Superintendent of the Geodetic Survey of Canada, March 31, 1918. The plan of the completed triangulation is shown on page 19 of this Report.

It will be noticed from the plan of the completed triangulation that a system of simple triangles is not used for determining the position of the stations; that it is attempted to fix the position of triangulation stations by more than one simple triangle so that the position of the station may be checked by at least two independent calculations. This is done in various ways—by the use of four sided figures with the diagonals also observed, or by having at least three lines observed to each station, thus providing the adjusting office two or more triangles by which the calculations to determine the position of the station may be checked.

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* *Commencement of the Survey where no Geodetic Stations are Available.*

In parts of the country which have not been covered by the Geodetic Survey of Canada, the engineer who starts the survey gets the best available maps of the country or makes a rough sketch of the area to be surveyed. After familiarizing himself with the general layout of the country, he selects a fairly level stretch of land on which a line, called a *base line*, may be measured with a precise metal tape line.

Determination of Latitude, Longitude and Azimuth.

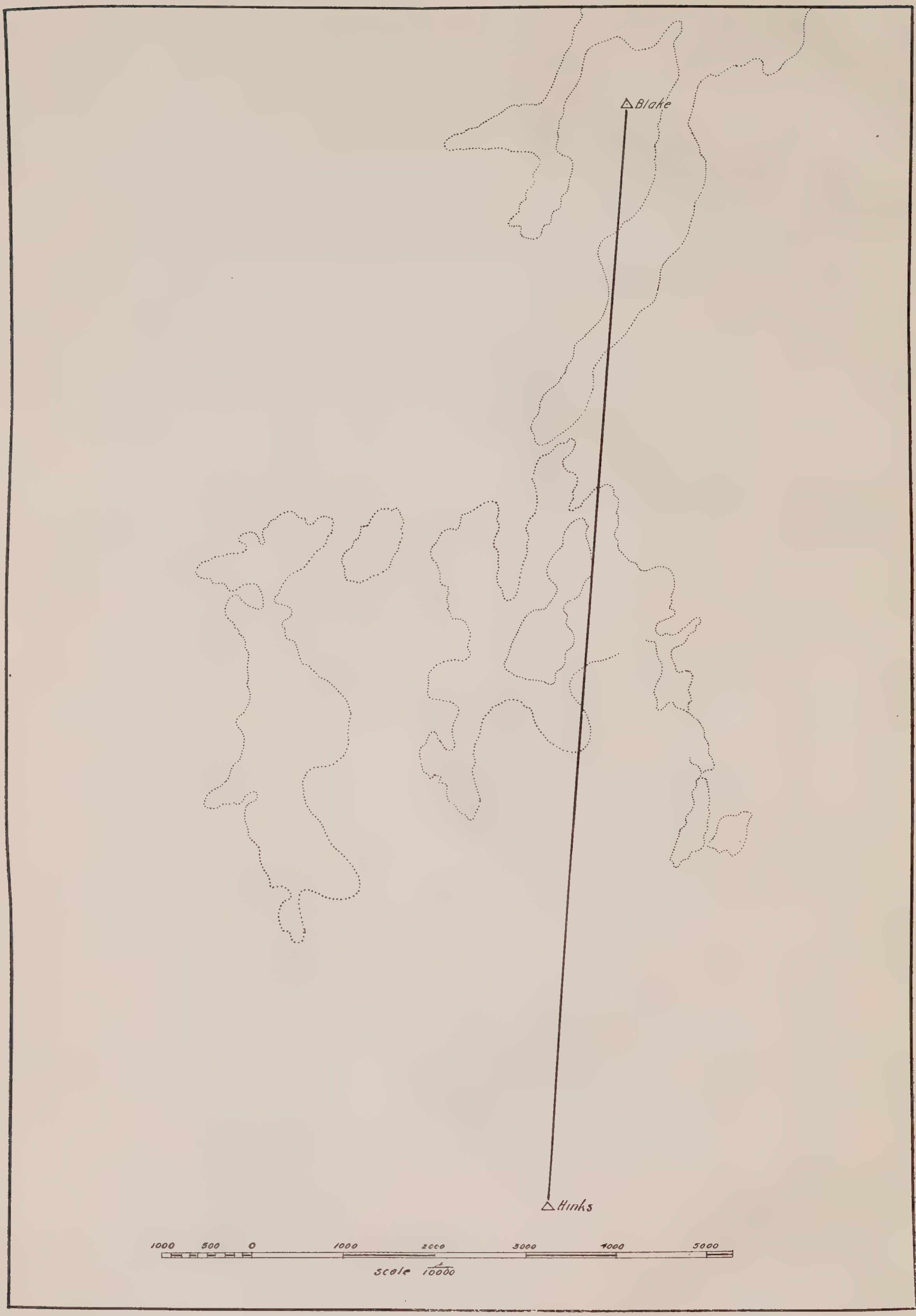
At one end of this *base line* very accurate observations are made on the stars to give the *latitude* (distance from the equator), *longitude* (distance from a north and south line through Greenwich, England) and *azimuth* (direction of the true north line at the station). By means of these observations the position of the survey on the earth's surface is found. The instruments used in these observations are illustrated on pages 20 to 23 in the Annual Report of the Superintendent of the Geodetic Survey of Canada, 1918.

It is to be noted that the latitude, longitude and azimuth obtained by this method are not as reliable as those obtained from the primary triangulation of the Geodetic Survey of Canada.

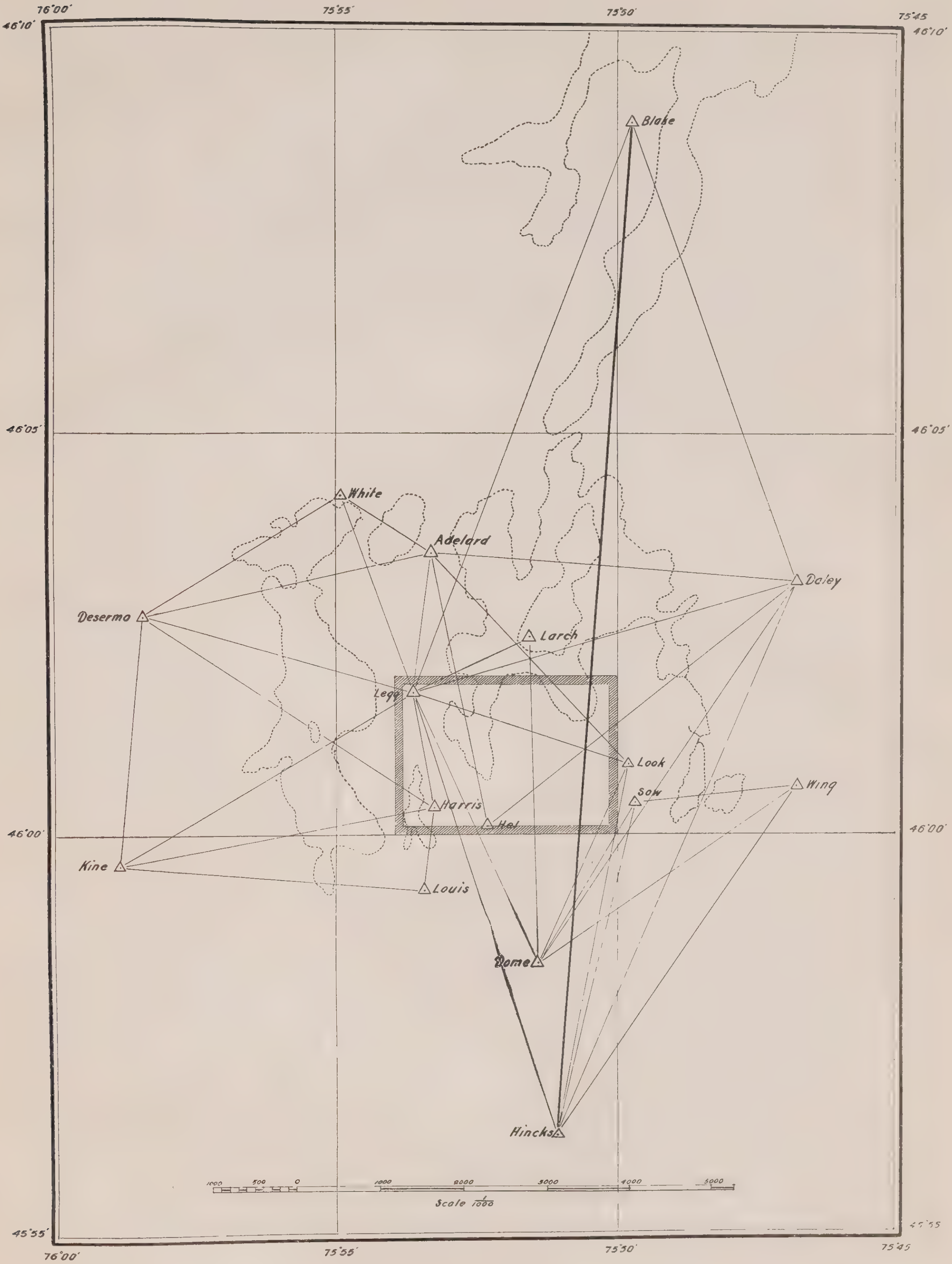
Base Line Measurement.

The length of the base line must be very exactly determined, as upon its accuracy depends the correctness of the length of many other lines in the whole survey which are not directly measured. The process of measurement may now be accomplished very exactly by the use of metal tapes made of *invar* (a nickel-steel alloy which scarcely changes its length with differences of temperature).

When the base line has been measured, the triangulation may be carried on in the same manner as has been described before.



Sketch showing Line of Primary Triangulation used as a Base for starting a system of Triangulation for making Topographic Maps



Sketch showing Completed Triangulation for Topographical Mapping.

NOTE: A topographic map of the section outlined in shaded border is shown opposite page 20.

Now commencing at our base line, the *latitude* and *longitude* of the ends of which are known, also the azimuth of the base line, we may use the distances and angles of our triangulation scheme to determine the *latitudes and longitudes* of all of our stations and also the azimuth of all of the lines of our system. On a sheet of drafting paper we draw the latitude and longitude lines to a selected scale and on this plan, called a projection, we may now plot the positions of all our triangulation stations ready for the actual mapping.

Levelling.—The operations which have been described before have had the function of controlling the accuracy of the horizontal measures of our map. There is one other feature shown on all topographic maps, *i.e.*, the height of hills, valleys, etc. Lines of levels are run along roads or railways and at intervals the elevations of permanent marks, called bench marks, are obtained in order that the map makers may have points whose elevations are known to control the accuracy of their more detailed system of levels all over the area to be mapped. The levelling instrument used is illustrated on page 64 of this report.

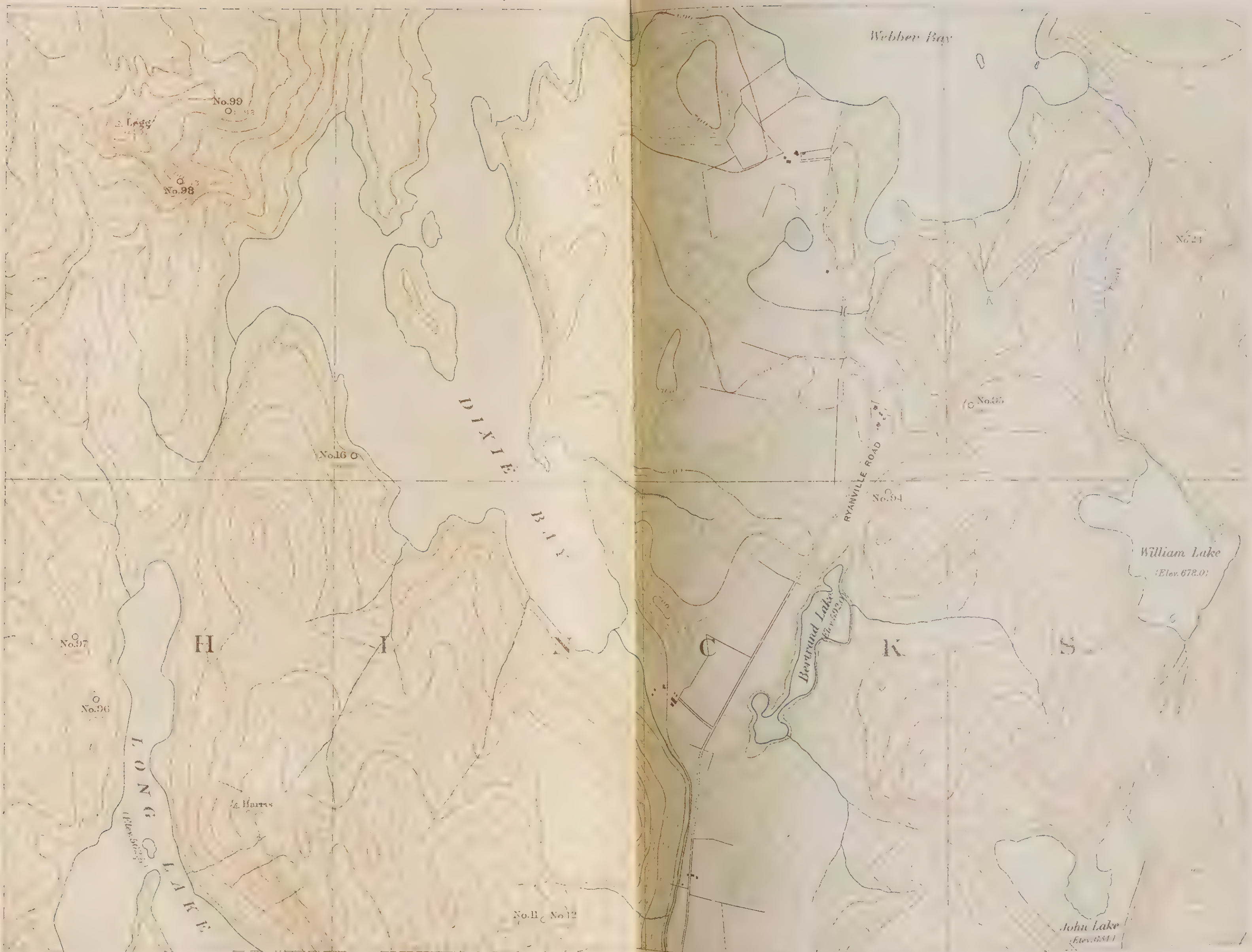
Topographic Maps.—The principal instrument used for mapping the details of a country is the plane-table. Other methods are in use, depending on the character of the country to be mapped. For instance in a mountainous country the camera is often used to great advantage; in fact many topographic maps may be compiled from surveys made by several different methods. A short description of the plane-table method, however, will be the only one given here, as it is the instrument of the most universal use for the making of a topographic map.

The plane-table outfit consists of a drawing board of seasoned wood mounted on a tripod, together with an *alidade,* which is a telescope attached to a metal straight edge so that the two are in parallel vertical planes. To be used with this instrument is a *stadia rod,* which is simply a piece of wood marked off in feet and fractions. By means of readings taken on these rods through the alidade telescope, distances may be found to within one or two feet. A photograph of a plane-table with stadia rods appears on page 21.

The plane-table, with the projection on top, is set up over the triangulation stations and turned so that the lines to other stations marked on the paper point directly to the corresponding stations on the ground; that is, the direction is the same on the plan as on the ground.

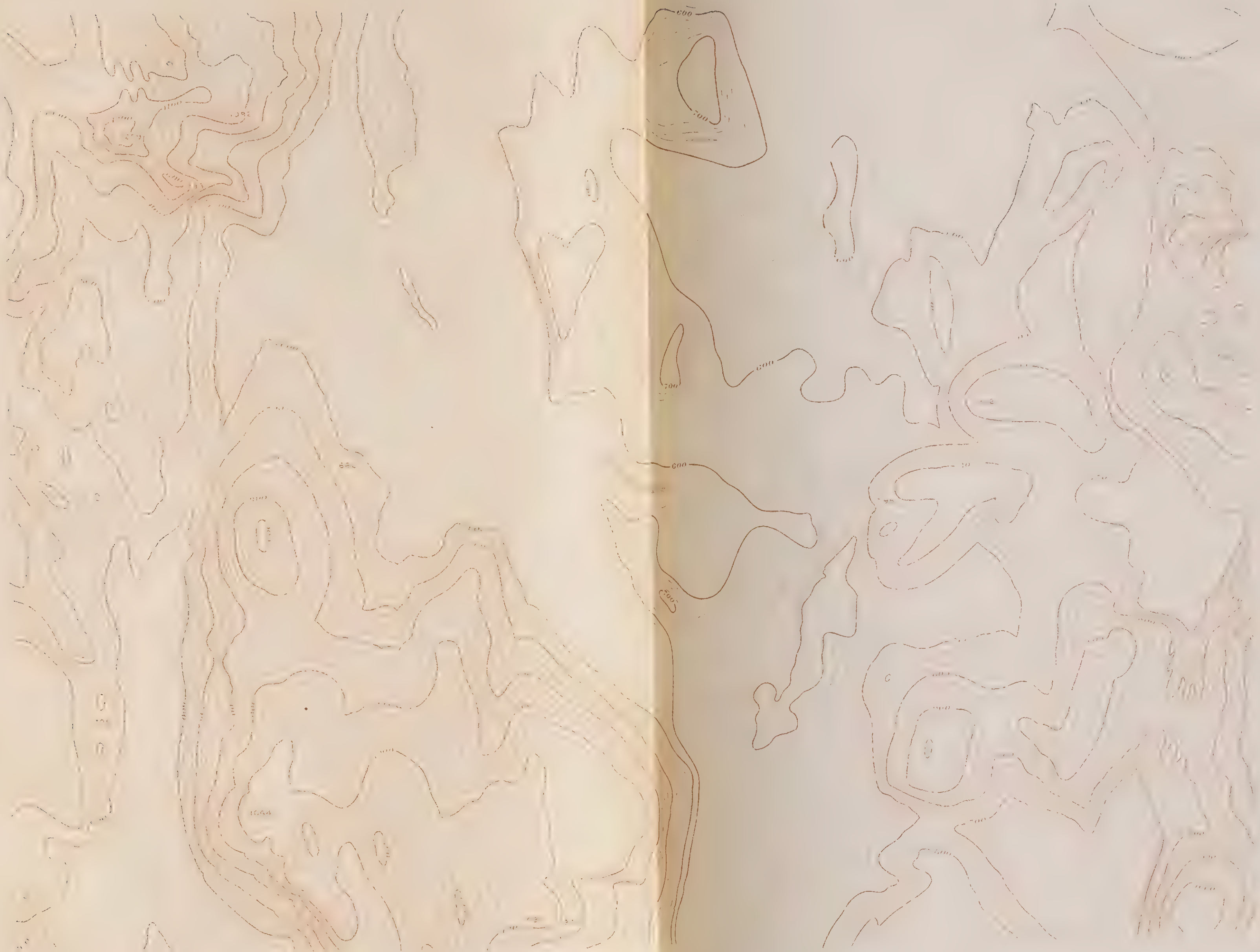
The alidade is now placed on the plan so that the straight edge passes through the point on the plan which represents the place occupied by the plane-table, the telescope is sighted at some object and a line is drawn along the straight edge on the plan. The object sighted on will be somewhere on this line. This shows the method of getting the *direction* to different objects. To get the *distance,* the stadia rod is held up at the object and the distance is read with the telescope. This distance is then plotted on the sheet. Were the course of a stream to be located on the map, the rod man would hold his stadia rod at each bend of the stream, the instrument man would locate the different positions of the rod on his map by the above method and join the points so located by a line. In a similar manner houses, bridges, fences, roads and all other features which have to be shown are located on the map. Thus is the topographic map made in the field and after it is inked in it appears as shown opposite this page.

Completing the Map, Engraving and Printing.—The field sheet as it appears inked in is a correct representation of the country and the next step is the reproduction of this sheet for use by the public. Several questions enter into this problem, such as the scale of the map, what method shall be adopted for depicting the different features, and what method shall be used for reproduction—engraving on copper, photo-lithography, etc.

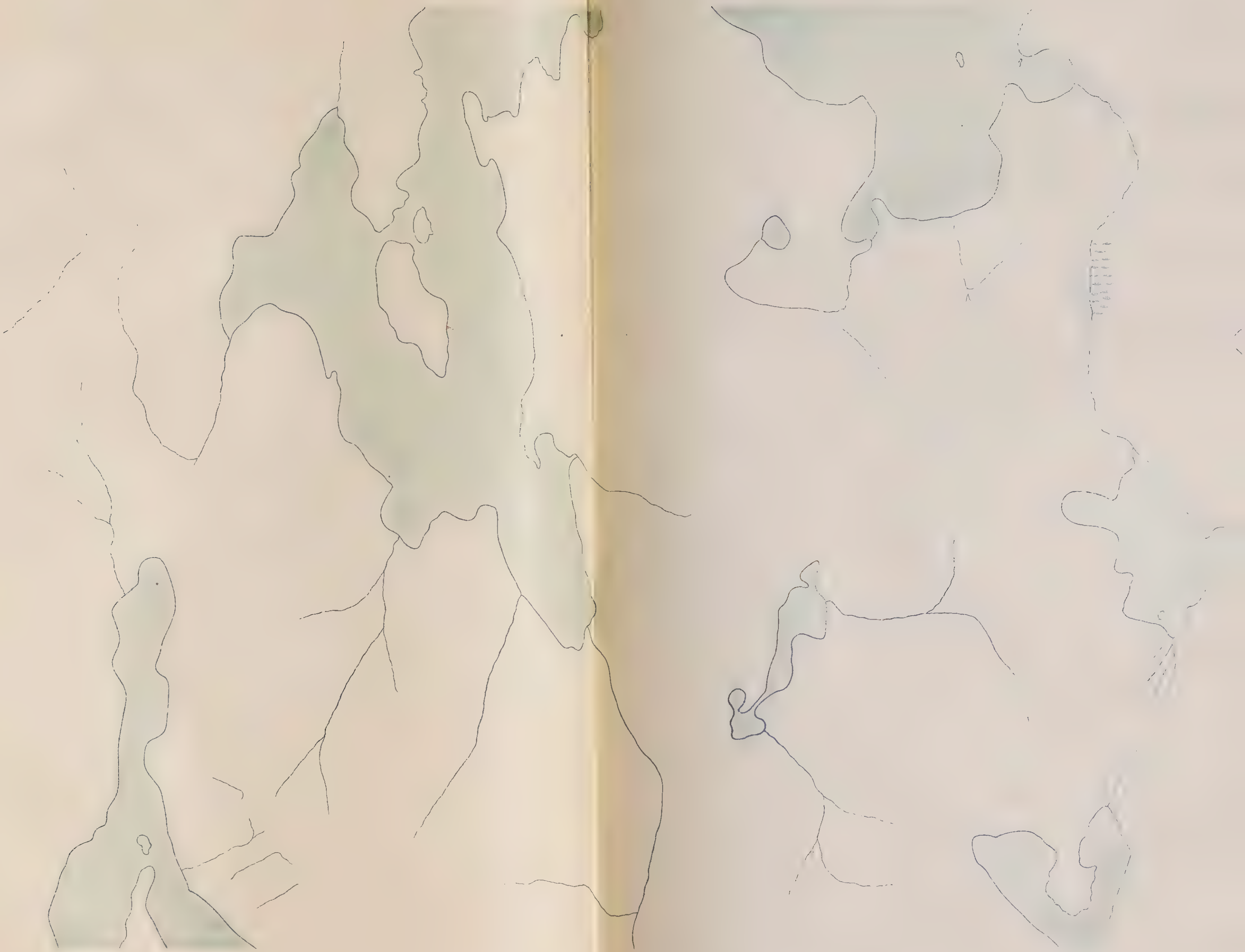


Topographic Map which depended for its accuracy on Triangulation.
(a) Completed Map.

Topographic Map which depended for its accuracy on Triangulation.
(b) Black Sheet.



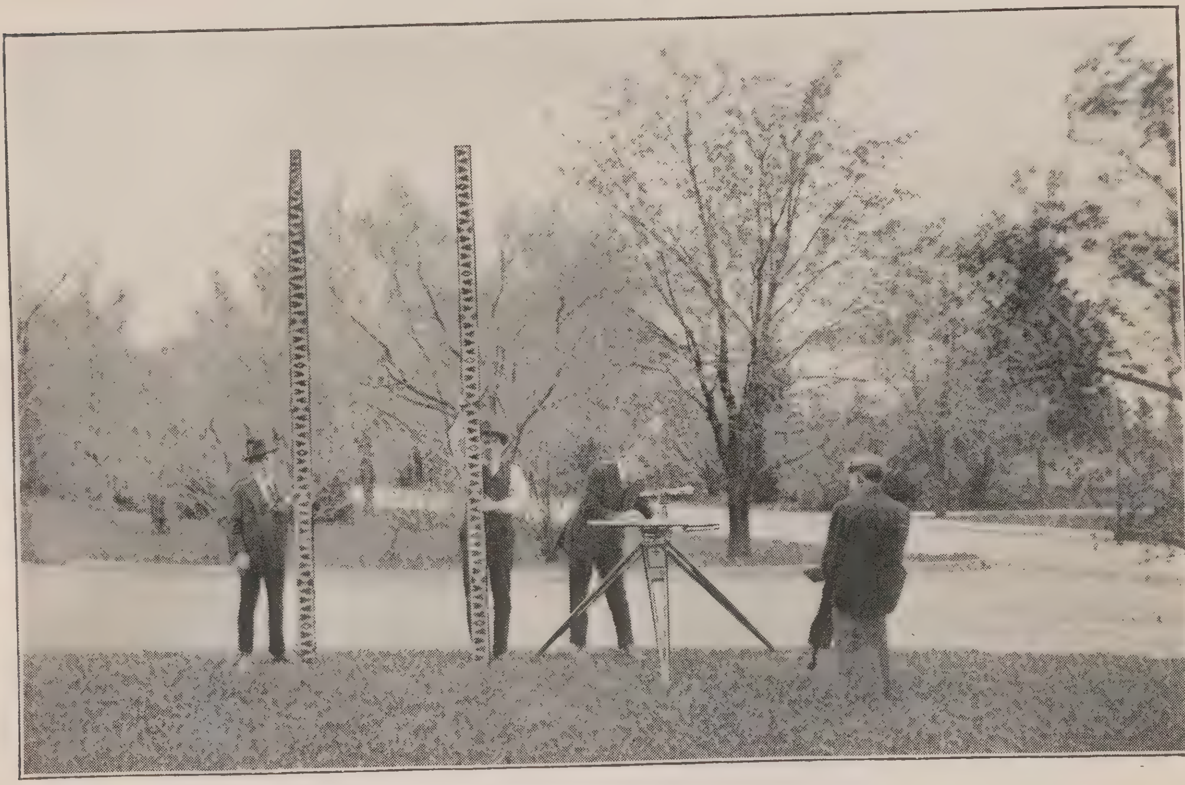
Topographic Map which depended for its accuracy on Triangulation.
(c) Brown Sheet.



Topographic Map which depended for its accuracy on Triangulation.
(d) Blue Sheet.

Topographic Map which depended for its accuracy on Triangulation.
(e) Green Sheet.

The latest designs of topographical maps are printed in four colours, each colour giving a certain class of information. The projection, lettering and all the artificial features, or those built by man, such as roads, railroads, buildings, fences, etc., being in *black*. The modeling or configuration of the terrain is shown by means of contour lines and spot levels, which give the elevation of country above mean sea level; these are printed in *brown*. All water features, such as streams, rivers, lakes, etc., are printed in *blue*. The symbols showing the various kinds of vegetation are printed in *green*.



Plane-Table Topographic Party, Showing the Plane-Table and Stadia Rods.

A separate plate must be made for each of the colours in which the map is to be printed; the features which will appear in black on the finished map are engraved or photo-lithographed on one plate, the brown on another, etc. This makes it necessary for the map to be run through the press once for each colour. The Black, Brown, Blue, and Green sheets appear opposite page 20.

There are three methods of printing maps in common use. First, printing direct from the copper plates on which the map has been engraved; this process gives very excellent results, but is very slow and expensive. Second, transferring from the copper plate to a zinc plate (rare) or stone. Third, transferring direct by photo-process from the drawing to the stone slab, zinc, or aluminum plates. In the latter two cases the stones, zinc, or aluminum plates are placed in the printing presses and the maps printed.

Basic Topographical Maps for Canada.

Topography may be described as the art of making a topographic map. *A Topographical Map* is the delineation upon a plane surface, by means of conventional signs, of the natural and artificial features of a locality.

Every point of the drawing corresponds to some geographic position, according to some method adopted for representing the surface of the spheroid on a plane, which is called the *Projection*.

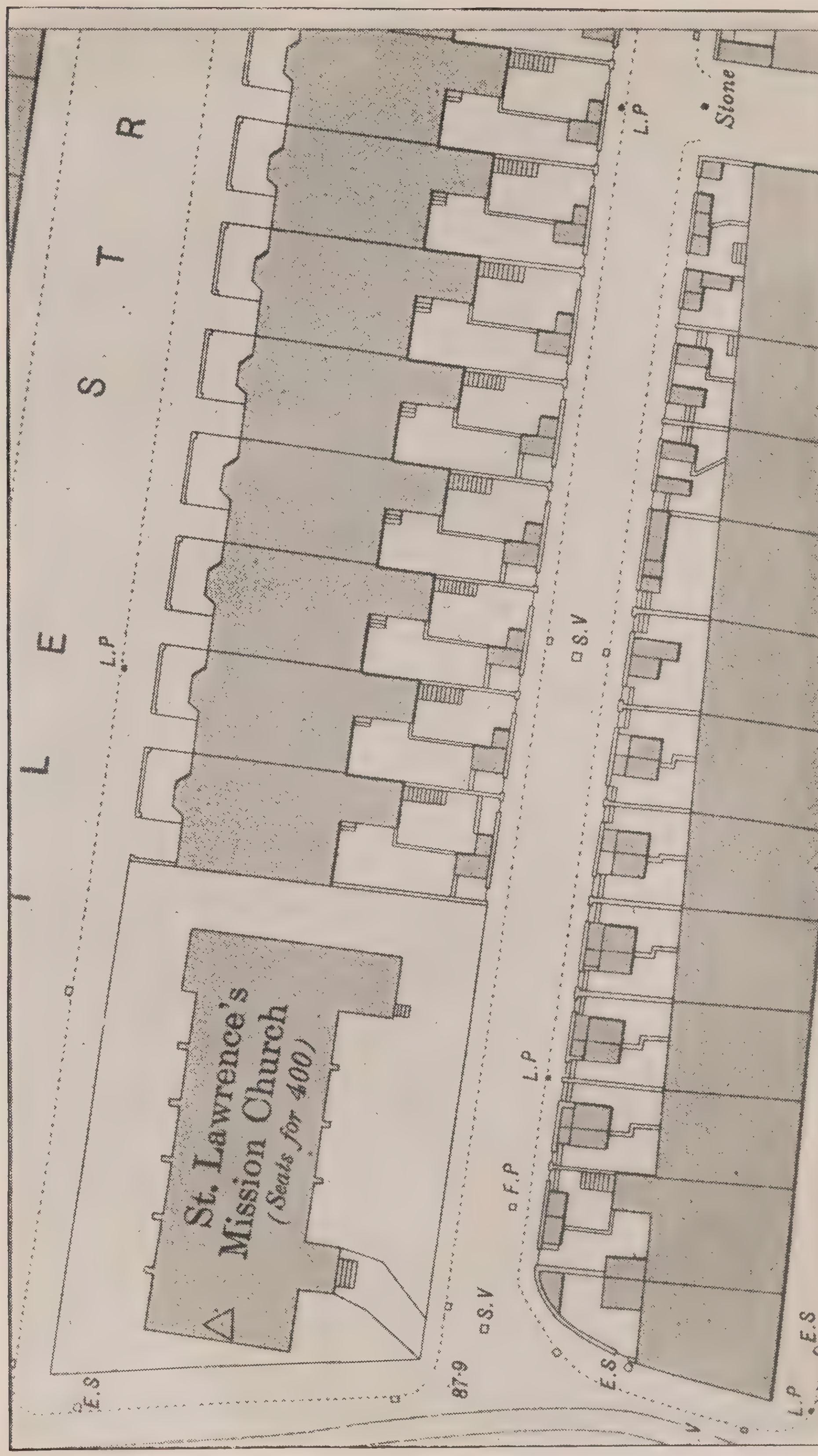
Since it is a representation in miniature, the distance between any two points on the map is a certain definite fraction of the distance between the same points in nature. This ratio is called the *Scale.*

Each point, besides being projected on a horizontal plane, has its elevation relative to a level surface in some way indicated. The level adopted for the map is called the *Datum Plane,* which in Canada is the *Mean Sea Level,* and the variation in the vertical element, the modeling of the country, is called the *Relief.* The relief on all up to date maps is shown by means of *Contour-Lines.* A contour-line in physical geography is a line drawn upon a map through all the points upon the surface represented that are of equal height above sea level. These points lie, therefore, upon a horizontal plane at a given elevation passing through the land shown on the map, and the contour-line is the intersection of that horizontal plane with the surface of the ground. The contour-line of 0. or datum level, is the coastal boundary of any land form. If the sea be imagined as rising 100 feet, a new coastline, with bays and estuaries indented in the valleys, would appear at the new sea-level. Were the sea to sink once more to its former level, the 100 feet contour-line with all its irregularities would be represented by the beach mark made by the sea when 100 feet higher. If instead of receding the sea rose continuously at the rate of 100 feet per day, a series of levels 100 feet above one another would be marked daily upon the land until at last the highest mountain peaks appeared as islands less than 100 feet high. A record of this series of advances marked upon a flat map of the original country would give a series of concentric contour-lines narrowing towards the mountain-tops, which they would at last completely surround. Contour-lines of this character are marked upon most modern maps of small areas and upon all government survey and military maps at varying intervals according to the scale of the map.

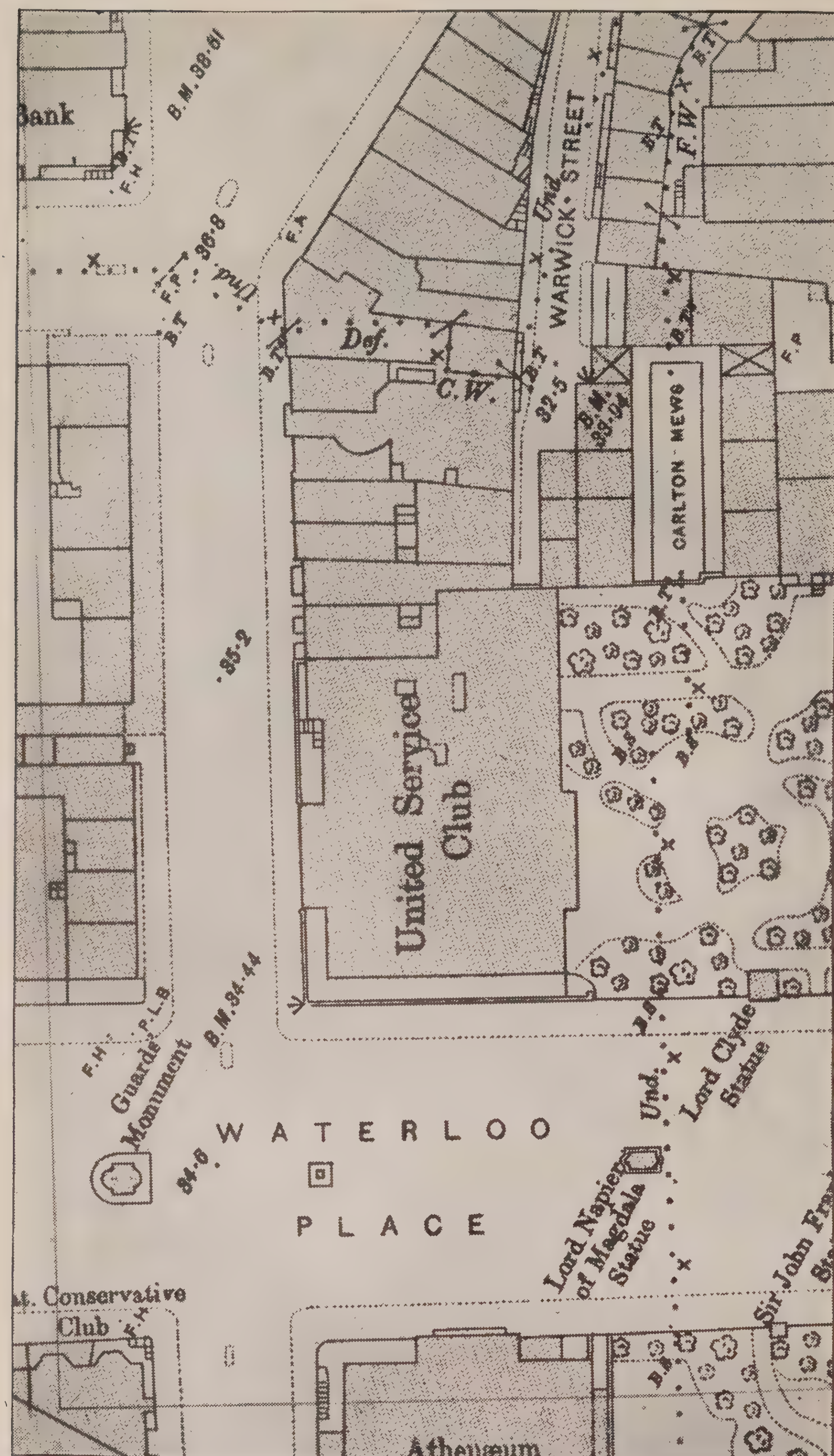
District and City Maps.—In order that Canada may develop along orderly and scientific lines, surveying work for a basic topographical map of cities, towns, villages and rural districts, should be started as soon as possible. The scale of the base map for rural districts should be 1-10,000, that is, one foot on the map represents 10,000 feet on the ground; for cities, towns and villages it should be 1-1,000, that is, one foot on the map represents 1,000 feet on the ground. These scales are large enough to represent to scale the most minute details in their respective areas and are large enough to calculate the approximate cost of any engineering work likely to be constructed. Maps on smaller scales for various purposes will be necessary, but once the base maps are made the smaller scale maps can be produced very cheaply without any field work.

In the United States the cities of Baltimore, Philadelphia, St. Louis, Cincinnati, New York and Washington have topographical maps. A table is attached giving information in regard to the style and information contained on them.

The health, intelligence and morality of the community depend upon the health, intelligence and morality of the individual, and this is to a great extent the result of the environment in which the individual lives and grows to manhood. Town-planning has, then, for its basic object the betterment of the individual through improving the environment in which he lives. That is to say, laws are passed which enable those who preside over the future destinies of the city to so control and regulate the growth of the city that the residential portions shall be in the localities most suited for healthy homes; that the homes themselves shall be built properly and not crowded; that the business section shall be in the most suitable situation; and that the manufactories shall be kept in the locality best suited to them.

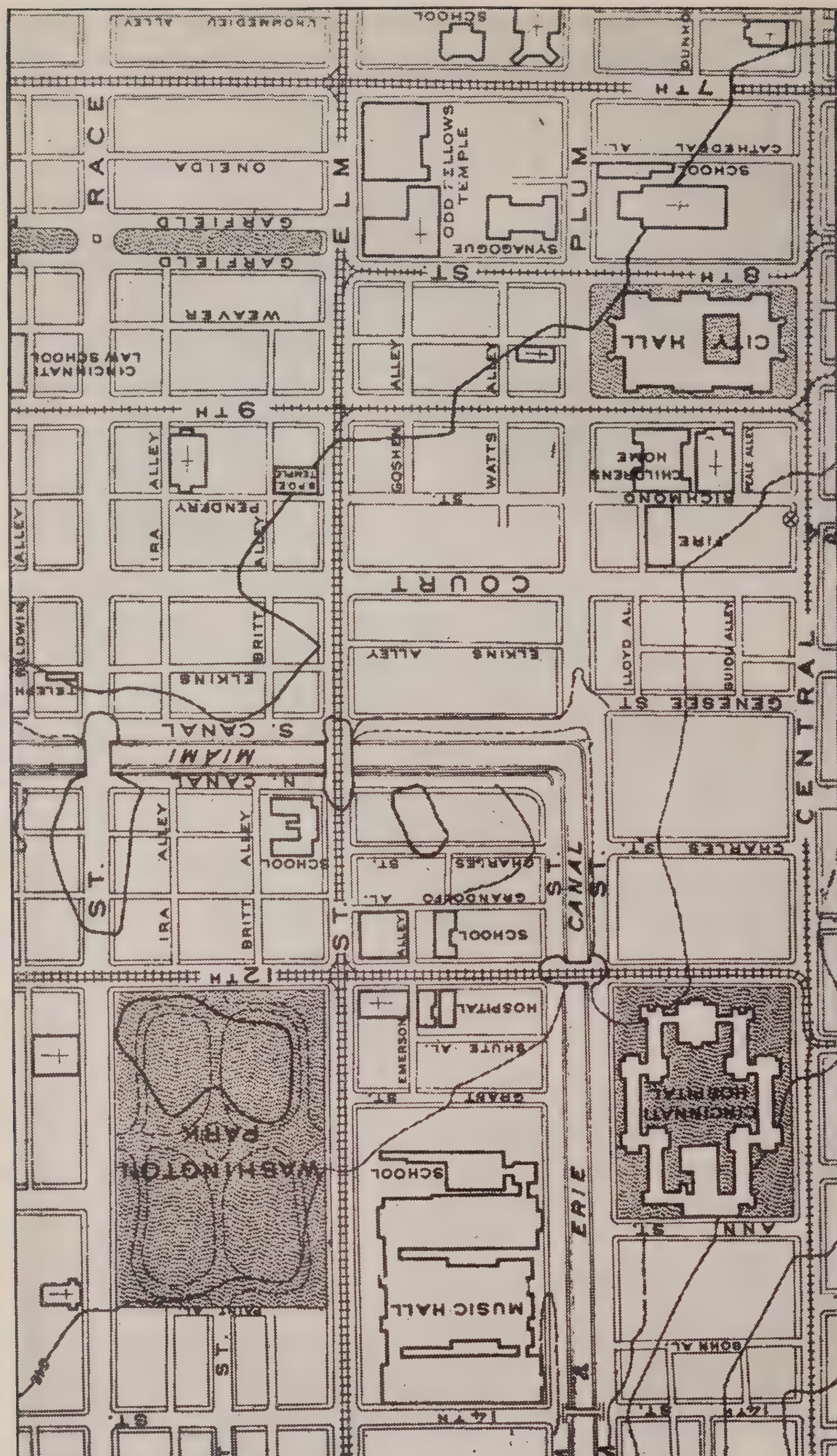


Specimen of the City of London, England, Map Published in black.
1-500 Scale.

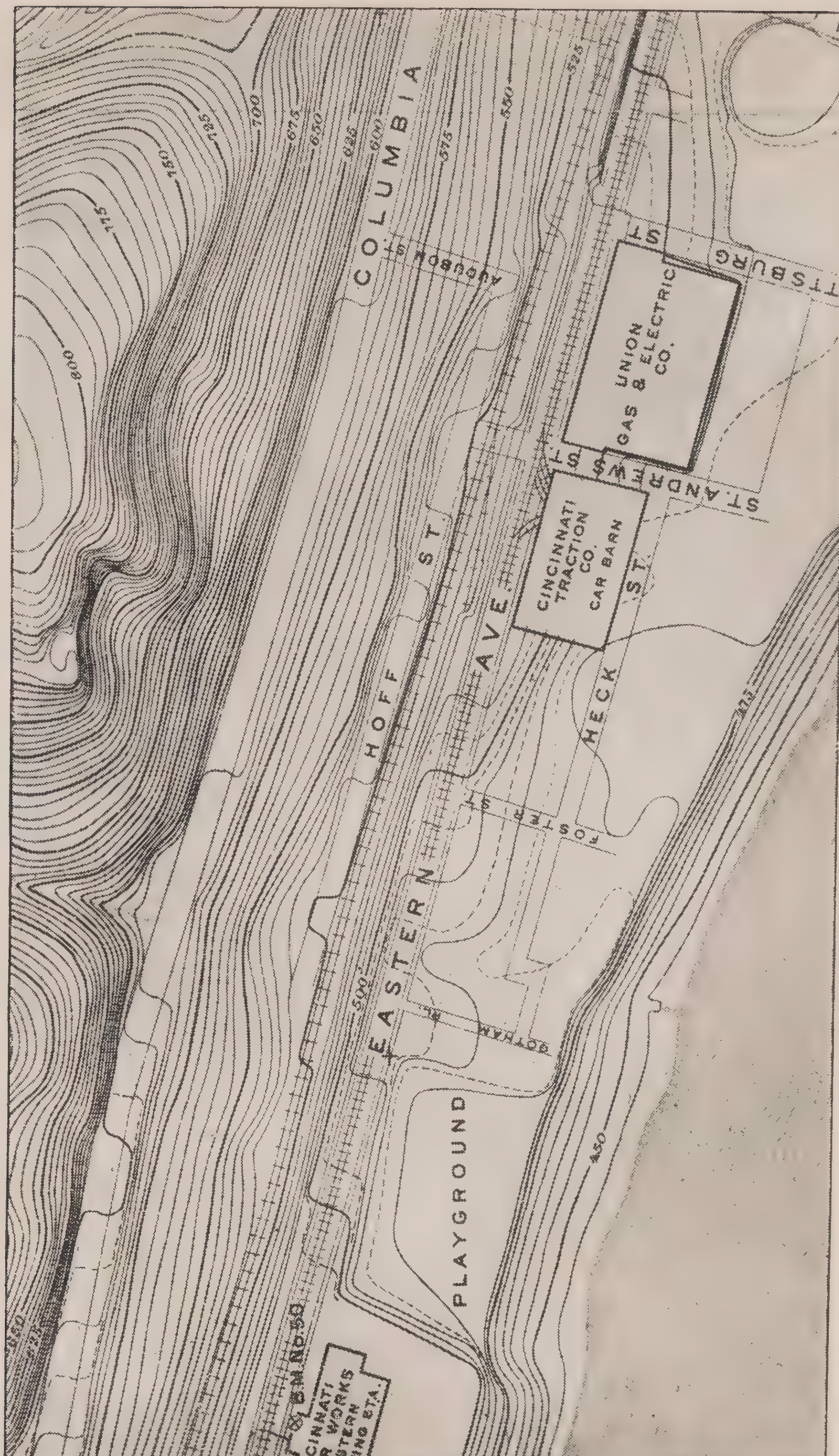


Specimen Map of the City of London, England. Published in black.
1-1056 Scale.

Specimen of an English map on a Scale of 1-10560. Published in black.



Specimen of the City of Cincinnati, Map. Published in black, brown, blue and green. Central portion of city. 1-4800 Scale.



Specimen Map of the City of Cincinnati, Ohio.
Published in black, brown, blue and green. Rural portion of city
1-4800 Scale.

In planning the localities for the different kinds of activities of city life various detail problems enter into the problem as a whole, such as transportation, involving location of railway tracks, yards and terminals, in regard to both passenger and freight service; rapid transit and street car service; the direction and width of roads; reclaiming of low and swamp lands and turning them into healthy parks and lakes; the location of sewers and water service, and many other problems which will be mentioned later on.

In order that the planning may be done in the most intelligent, systematic and economical manner it is absolutely necessary that there should be a large-scale topographical map of the city and the surrounding district which come under the town-planning scheme. Besides town-planning, these maps will form the basis of all the work and records of the city's engineering department, and also other city departments.

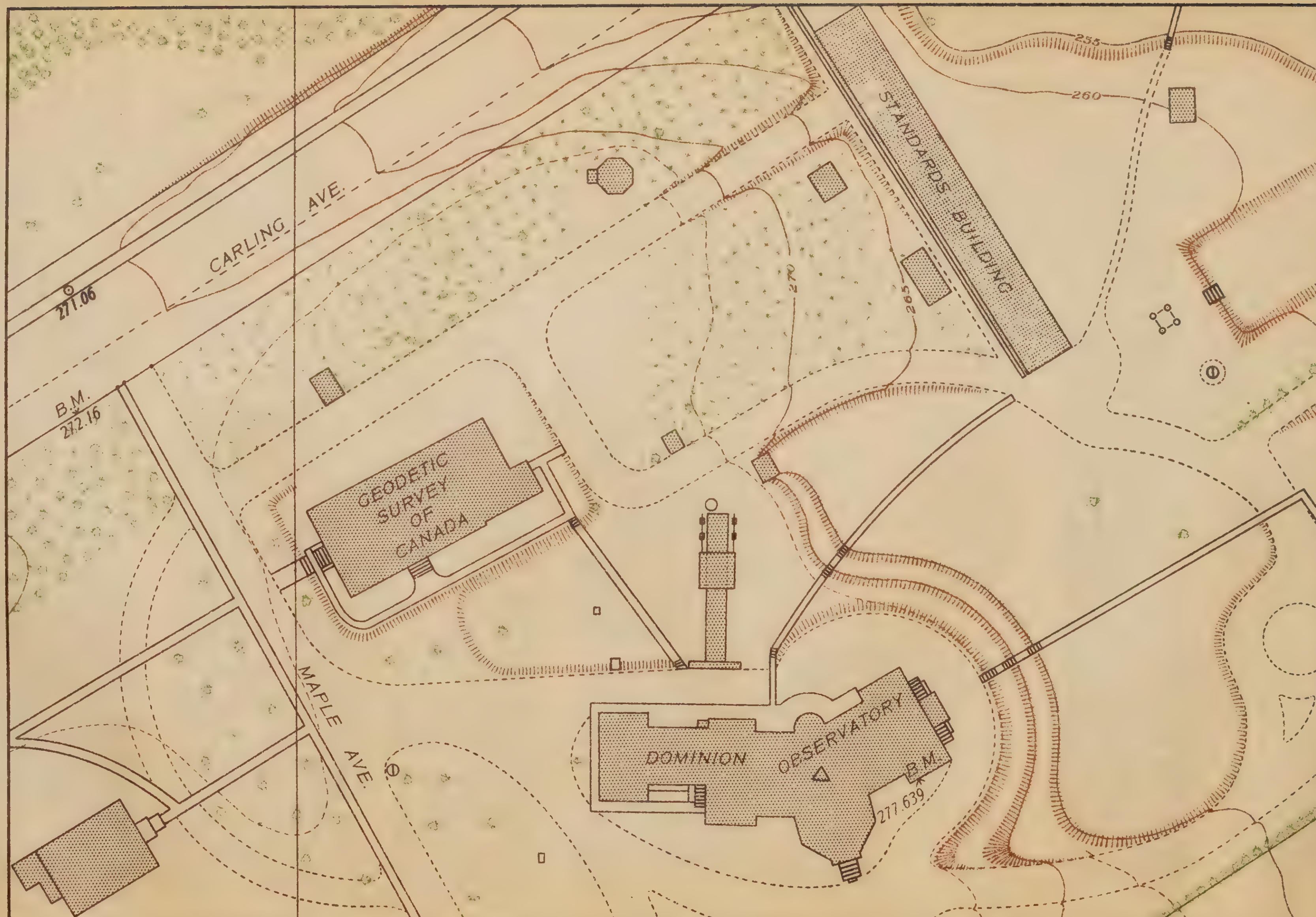
The mapping of cities and towns in Canada on a large scale has not yet been attempted, but it is most important that such maps should be prepared as will be shown during the course of this article. This is especially so because of the extent to which land has been sub-divided beyond the limits of built-upon areas in most of our Canadian cities.

Uses of Map.—In deciding the scale on which the map is to be published we must examine the different purposes for which it will be used. They may be enumerated in part as follows: for city planning, for planning relief and storm sewers, or a complete sanitary system and the location of disposal works; for planning and laying out a complete water system or extensions; for locating new streets and roadways; altering or closing existing highways; reserving land for new main thoroughfares; determining building lines or set-backs of buildings according to a comprehensive scheme for a large area; for improving creeks; for landscape and parks works; for bridge works; for railways, their terminals and yards; for tunnels and canals; for gas pipe lines, electric wiring lines, and telephone lines—even for architectural work. Planning of zones in urban parts of rural areas within which to regulate different degrees of density and height of buildings, according to local conditions.

Classifying land for use for residential purposes, factories, agriculture, etc., and adjusting the system of taxation and the system of planning and constructing local improvements to suit the kind of development permitted under the scheme layed out. Laying new subdivisions; cancellation and re-planning of old subdivisions. Planning of private and public open spaces for recreation. Planning extension of variation of private right of way and other easements. Planning of community centres and educational institutes.

It will be seen from the foregoing that the uses to which a city map will be put are many and varied. The waterworks engineer will have a complete set upon which he will show all water and sewer lines. The road and sidewalk department, the driveway and parks department, the gas companies, the electric companies, the railway companies, the telephone companies, and many other smaller concerns and private individuals will each have a set upon which they can show such work as is already completed, and also design and calculate the cost of new extensions.

Data shown on Map.—Having examined the uses to which the map will be put, we find that it will be necessary, in order that it will be of the greatest value to all, for it to show the following data: buildings, sidewalk and road lines, trails and foot-paths, fences, boundary lines, railroads, canals, streams, rivers, lakes, tunnels, bridges, dams, locks, wharves, docks, jetties, breakwaters, ferries, fords, falls and rapids, marsh, hydrants, manholes, drainage grates, trees, triangulation stations, primary traverse stations, bench-marks, located land monuments, and the elevation and form of the ground surface by means of contours.



Specimen of Proposed 1/1000 Scale Canadian City Map to be Published in Black, Brown and Green

It should also show the difference between public buildings, business buildings and residences.

And finally, before deciding upon the scale of the map, let us see what other countries have done in this respect.

Memorandum on Large-scale Maps of Great Britain.—"Town maps of the whole of the United Kingdom have been prepared on various scales. In England and Wales 408 towns, and in Ireland 105 towns, have had plans prepared and published in the ordinary course of the survey on large scales; and, in addition to these, large-scale plans of 33 smaller places in Ireland have been prepared but not published.

"The first scale adopted was 5 feet to a mile, or 1/1056 the actual measurement on the ground; the plans of London, Dublin, Belfast, and some smaller towns are still on this scale, and the original plans of the towns in Yorkshire, Lancashire and the South of Scotland were prepared and engraved upon this scale.

"There are also a few places that have plans on the scale of 10 feet to a mile, or 1/528 the actual measurements. But the rule from 1855 to 1894 was to prepare and publish the plans of all towns which at the time of the survey had 4,000 inhabitants and upwards on a scale of 1/500, or 10·56 feet to the mile. Most of the towns in the United Kingdom therefore (London, Dublin and Belfast being, as above said, exceptions) have plans on this scale, which is large enough to show doorsteps, the thickness of walls, and the divisions of buildings. Most of the town plans also show all objects connected with water supply, lighting and drainage, such as hydrants, sewers, manholes and gratings. Levels are shown along the streets and bench-marks are cut at frequent intervals, showing to two places of decimals the altitudes above mean sea level. Areas are not shown on the town plans."

The plans on the scale of 1/500 are similar in size to the 1/2500, or 25-inch plans, namely, about 36 x 25 inches, and contain an area 24 x 16 chains, or 38·4 acres.

Maps on a scale of 1/2500, or 25·34 inches to the mile, are published for the whole of the cultivated districts of Great Britain, and the survey of the cultivated portions of Ireland is in progress.

Maps on a scale of 1/10560, or six inches to the mile, can be obtained for the whole of the United Kingdom.

The 1/1000 Scale for Canadian City maps.—A scale of 1 foot equals a thousand feet, or a natural scale of 1/1000, would enable us to show all the necessary detail. It would be an easy scale for an engineer to make calculations from, a scale economical from the standpoint of the topographical engineer, and one from which accurate measurements could be taken either in feet or metres. The topography on the published sheets of this scale would cover $25\frac{1}{2}$ inches by $36\frac{1}{2}$ inches, and the bounding lines would be parallels of latitude and meridians of longitude, enclosing thirty seconds of each, which would measure on the ground a space 2,100 feet by 3,050 feet. This particular size of sheet is chosen for two reasons: first, to cheapen the cost of publishing the 1/10000 scale maps; and secondly, to give a universal system of numbering the sheets which would be applicable anywhere in Canada. It whould take just 100 sheets of the 1/1000 scale to make one sheet of the 1/10000 scale. They would, therefore, be numbered from one to a hundred, and the number of the 1/10000 scale sheet attached, as well as that of the degree of the International map of the World, published on a scale of 1/1000000. The number of the International map sheet would also be given.

On this scale the convergence of the meridians could not be shown. The latitude and longitude lines which would form the boundaries of the topography would, therefore, be drawn at right angles to each other. The projection lines of the sheet, for the convenience of making measurements from it for engineering purposes, would be latitude and departure lines, drawn one thousand feet apart, and having for their zero some geodetic triangulation station.

Public Uses of the 1/10000 Scale Topographic Map.—The whole of the United Kingdom of Great Britain and Ireland is mapped upon a 1/10560 scale. The city of Cincinnati is now publishing a smaller scale of wall-map on a scale of 1/14400. The 1/10000 maps would be published in sheets, representing five minutes in latitude and five minutes in longitude, which measures, on the ground, four miles east and west and five miles 4,000 feet north and south. On paper, the topography would cover a space of 25½ inches by 36½ inches. If 144 square miles were to be taken for the proposed Federal District of Ottawa, six of these sheets would cover the district, and if mounted on linen, would make a wall-map six feet and five inches wide and six feet and one inch high.

Dominion or Provincial Government.—For the purposes of the Dominion or Provincial Government good topographic maps are invaluable. They furnish the data from which the member of Parliament or legislator can intelligently discover most of the information bearing directly upon the problem in hand and they give the committees great assistance in their decisions as to the need of legislation. If a river, harbour or canal bill is before Parliament, by an inspection of such maps the slopes of the country through which the canal is to pass or in which improvements are to be made may be easily ascertained.

The Department of the Interior.—Engineering Data.—for designing and making estimates for the construction, operation, maintainance and development of roads, railroads, canals, irrigation schemes, drainage ditches, swamp reclamation, hydro-electric power plants, electric power lines, telephone and telegraph lines, wireless stations, aerodrome parks and sheds, air-ship hitching-post stations, etc., can be easly and quickly ascertained from such maps.

It is difficult to see how any systematic or economical plan of *road impro-ments* can be advantageously made without the knowledge of existing grades, the physiography of the district though which the roads pass, and the location of quarries, gravel and sand pits, which such maps present. They furnish nearly all the data necessary to a road map for automobile touring. In community enterprises they give information to assist in organizing facilities for purchasing, marketing and other co-operative activities connected with inprovements of services necessary for the efficient organization and development of any community.

The Land Departments of the Dominion or Provincial Governments can discover on such maps not only the outlines of the property under their jurisdiction, but its surface formation, also information in regard to, soil classification, areas available for agriculture, village and town sites, developments of minerals, coal, waterpowers, water reservoirs, parks, the extent of crown lands, etc.

Forestry Boards can see upon these maps the outlines of the wooded areas, the slopes of the land on which these woods are situated, their relation to highways of transportation, railways or streams, and the slopes to be encountered in passing through the woods. Information in regard to classification of trees and other vegetation, commercial value, areas suitable for clearing, for forest preserve, for ten year rotation crops, etc.

Department of Public Works.—This is one of the large departments of the government and it is necessary that it should be supplied with the largest amount of information possible in order that its decisions in regard to the construction of public structures such as canals, dams, locks, harbour and

river improvements, should be the wisest possible. Good topographic maps supply a large part of this information.

Militia Department.—If it is desired to locate an arsenal, encampment ground, or other military work, or, above all, if it is to conduct active military operations in the field, such maps serve all the purposes of the best military maps and make a perfect artillery map, as the fences, ditches and the smallest outbuildings are shown on this scale.

Post Office Department.—For the Post Office Department or private stage, express, telephone or telegraph companies, such maps furnish the basis on which an accurate understanding can be had of contracts submitted for rural or other routes for carrying mail or packages. As these maps show the undulations of the surfaces over which roads pass, their bends and their relative differences in length, the difficulties in travel on competing roads can be readily ascertained from them.

The Department of Justice.—The legal department of the Dominion or Provincial Governments finds these maps of service in discussing political or property boundary lines, in ascertaining within what political division crimes are committed or individuals reside with whom the officers of the law desire to communicate.

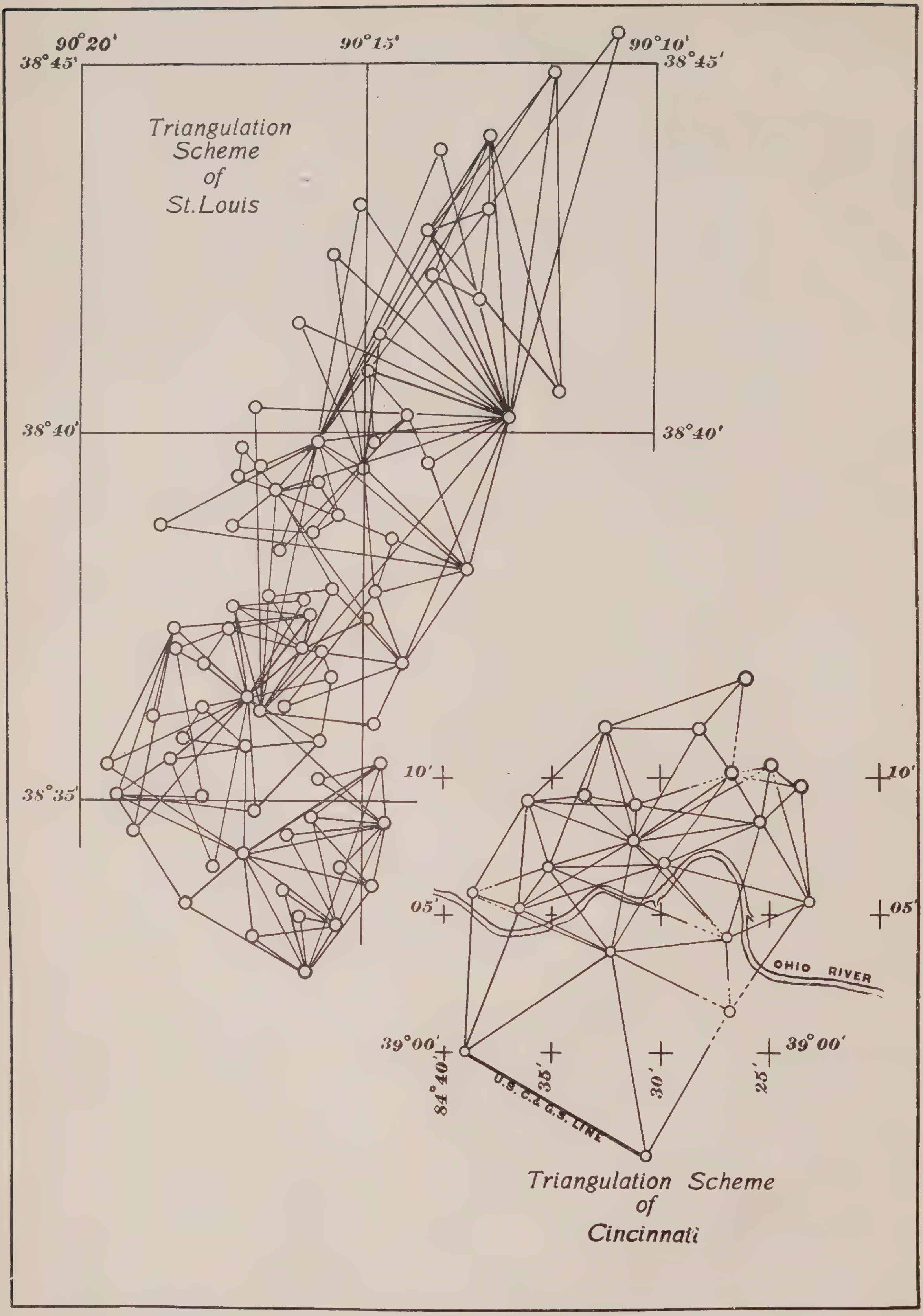
The Department of the Naval Service.—This department will find a map on this scale useful as a base map for hydrographic charts where navigation is dangerous or difficult. Reductions from this base map will make the compilation of charts on a smaller scale, quick, easy and inexpensive.

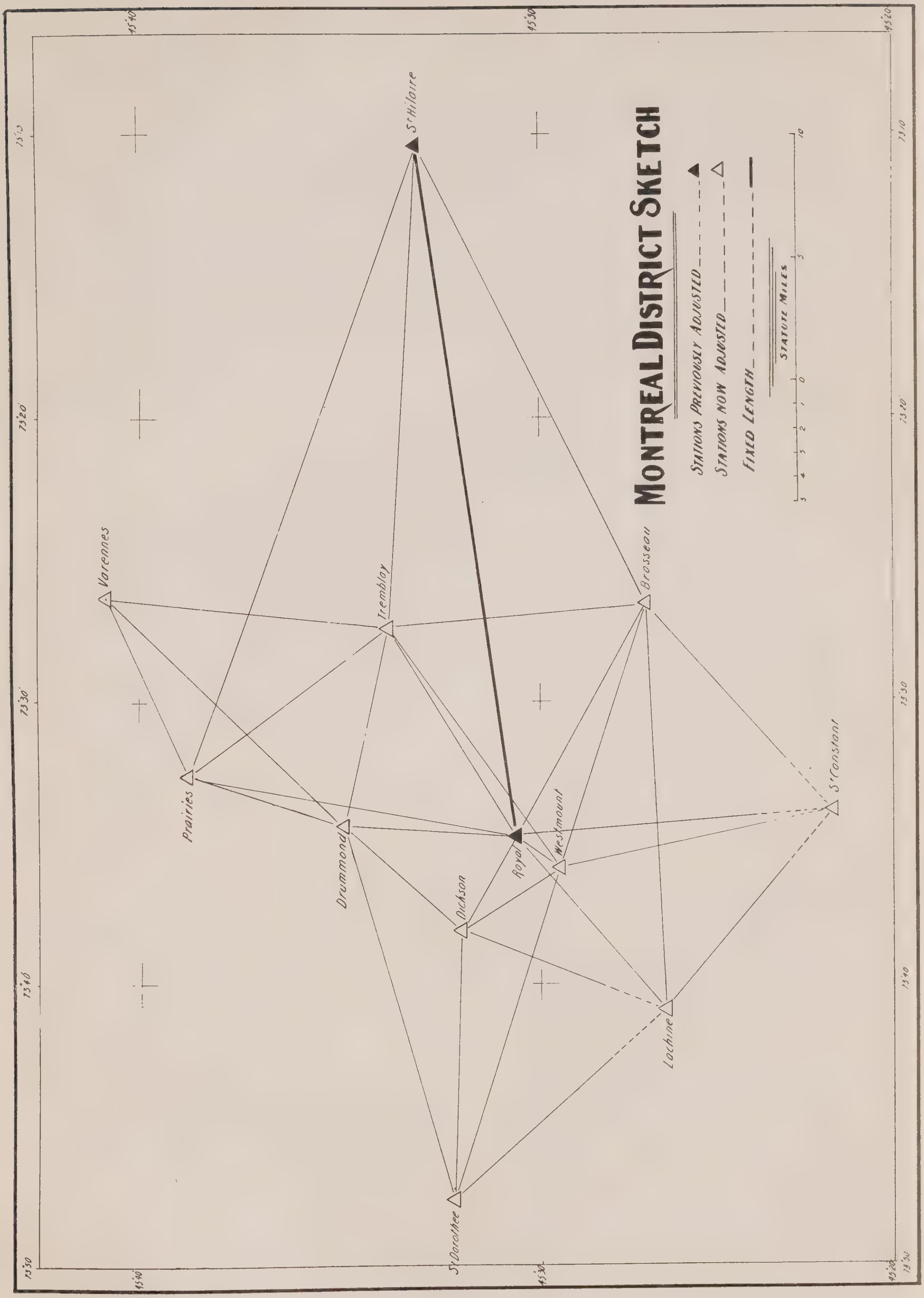
Department of Mines.—Detailed geology can be plotted on this scale, which is large enough to enable a mine shaft to be plotted to scale.

System in Field Work for Making Maps.—An editorial in the "Toronto Daily News" of January 26, 1916, upon this subject under the title of "Surveying Cities", says in part:—

> "When the first New York Subway was constructed one of the chief difficulties facing the engineers in charge of the excavation was the continuous discovery of 'Lost" water-mains, sewers and wire conduits. Maps of the city were in the Works Department and it was believed that these marked in full detail every under-ground service. Devices for supporting the mains and pipes were provided for in the estimates, but often calculations were twisted awry by the lost mains as they were disclosed in unexpected places.
>
> This is a young country. Our cities are not yet of metropolitan size, and there is much talk of Town-Planning. This is the time for us to avoid future trouble by preparing complete and accurate Topographical Surveys of all cities and towns. Such a survey would mean detailed mapping, and the maps, both of large and moderate scale, so provided would be the Bible of the working departments of the municipal governments. The subject is too technical for general discussion, but no one will deny that a plan of action which is adopted in all the cities of England and which is awaking engineering interest in the cities of the United States might well be a subject of careful inquiry in Canada."

The whole system of making successive *special surveys* or maps for every new need is one of the most wasteful in our present public practice, nor can it be otherwise until *one survey* shall be made that answers all important official uses. The amount of money that has been expended on making numerous special surveys of different sections of the country to get special information, would have mapped on a general scale many times the area of the country. Even when we have these special maps they do not fully answer the purposes for which they were intended, as they only show the small area included within the immediate plan of operations. The value of a stream for economic purposes cannot be fully ascertained by an examination of the stream at the point from which it is to be used, but the drainage basin from which it derives its supply should be surveyed, and its area and its slope be known. A good topographic map not only shows the relations between the natural and artificial features in the immediate neighbourhood under consideration but it shows the relations of these to the surrounding country.


90°20'
90°15'
90°10'
38°45'
38°45'
Triangulation Scheme of St. Louis
38°40'
38°40'
38°35'
10'
10'
05'
05'
OHIO RIVER
39°00'
39°00'
84°40'
35'
30'
25'
U.S. C.& G.S. LINE
Triangulation Scheme of Cincinnati


MONTREAL DISTRICT SKETCH
STATIONS PREVIOUSLY ADJUSTED
STATIONS NOW ADJUSTED
FIXED LENGTH
STATUTE MILES
St Hilaire
Varennes
Tremblay
Brosseau
Prairies
Drummond
Royal
Westmount
Dickson
St Constant
Lachine
St Dorothee

MAP STATISTICS OF CITIES.

City.	Scale.		Size of Sheet.	Colours used in Printing.	Projection.		Contour Interval	Monuments shown.	Cost.			Remarks.
	Inches to Feet.	Natural.			Lat. and Dept.	Lat. and Long.			Per Acre.	Per Sq. Mile.	Cost of Sewage per Acre.	
									$ cts.	$ cts.	$ cts.	
London, England	1″ to 88′	$\frac{1}{1056}$	24″ by 36″	Black	....	....	None	B. M. Tri. Sta. ...... Tra. Sta.	3 25	2,080 00		
English, Scotch and Irish cities.	1″ to 41·7′	$\frac{1}{500}$	24″ by 36″	Black	....	....	None.					
Baltimore	1″ to 200′	$\frac{1}{2400}$	26½″ by 26½″	Black Brown Blue	1000′	Indicated on edges.	5′	B.M. Tra. Sta. Tri. Sta.	7 62	4,880 00	....	Trees in black.
Philadelphia	1″ to 200′	$\frac{1}{2400}$	36″ by 60″	Blue Print Map not Published	1000′	....	5′ 2½′ dotted	B.M. Tra. Sta. Tri. Sta.	......	....	....	Map not printed.
St. Louis	1″ to 200′	$\frac{1}{2400}$	28″ by 50″	....	....	....	3′	B.M. Tri. Sta. Tra. Sta.	1 54	965 60	638 00	Rated by a town lot the cost is 14½ cents per lot.
Cincinnati	1″ to 400′	$\frac{1}{4800}$	28½″ by 20½″	Black Brown Blue Green	2000′	Indicated on edges.	5′	B.M. Tri. Sta. Tra. Sta.	......	....	....	Park shown in stippled green 2½′ contours dotted.
New York	1″ to 200′	$\frac{1}{2400}$	20″ by 25″	Black	1000′	....	5′	Tra. Sta.	......	....	....	Vegetation not shown. Measurements of blocks, sides and traverse lines shown.
Washington	1″ to 400′	$\frac{1}{4800}$	13½″ by 13½″	Black Brown Blue Green	....	Indicated on edges.	5′	None shown.				

REQUESTS RECEIVED DURING THE FISCAL YEAR.

Realizing that the Geodetic Survey of Canada, by its triangulation and levelling schemes, should be the basis of all survey work, requests were made by the Department of Public Works and the Department of Mines for triangulation and level work to control the Fraser river engineering scheme. The British Columbia coast triangulation is to be extended up the Fraser river so as to become the basis for the Fraser river engineering scheme in this vicinity.

Thus this Fraser river engineering scheme is one of great importance not only to the engineering world generally, but because of its great practical value to the city of Vancouver.

That the Geodetic Survey of Canada is being more and more considered as an aid to other engineering bodies is shown not only by the above Fraser river engineering scheme, but by the desire expressed by the cities of Montreal, Toronto, Halifax, Vancouver and Winnipeg to have such control given them by the Geodetic Survey as may enable them to proceed with their detailed topographic maps.

In the case of the city of Montreal control for a detailed topographic map will be given by the establishment of a triangulation scheme in and around the city. This scheme, together with the triangulated positions of a large number of church spires, flagstaffs and points on buildings, all of which are referred to monuments placed on the streets of the city and surrounding municipalities, will serve as a basis to control the accuracy of the measured traverses and topography. (See sketch on page 33 for the triangulation scheme on which the positions of all points in the city of Montreal and vicinity depend.)

It is to be remarked that for so important a control survey as that of the city of Montreal, the expenses to be borne by the Geodetic Survey of Canada will be extremely small, as all the material required for the erection of the towers is to be furnished at the cost of the city of Montreal, so that the only extra charge beyond the salaries of the field engineers to be borne by the Geodetic Survey of Canada, is that which will be due to the cost of the maintenance of said engineers while engaged in their work in Montreal.

Several similar requests have been received by the Geodetic Survey of Canada during the fiscal year.

PUBLICATIONS.

In conformity with the practice of this Survey in issuing publications which contain:—

(a) All the data made available by the operations of the Survey for the use of engineers, surveyors and surveying branches of the Government.

(b) Geodetic and topographic methods of both field and office work, a knowledge of which will be of use to all engineers and surveyors prosecuting geodetic and topographic work in this and other countries.

there were issued during the past year:—

Publication No. 1.—Precise Levelling—Certain Lines in Quebec, Ontario and British Columbia—by F. B. Reid.

As this report is being prepared, there are in press the following publications:

Publication No. 2.—Geodetic Triangulation —by W. M. Tobey.

Publication No. 3.—Standards—by F. A. McDiarmid.

Publication No. 4.—Precise Levelling. Certain Lines in Ontario and Quebec—by F. B. Reid.

The following are summaries of reports of the officers in charge of the various sections of the work of the survey in 1918.

Respectively submitted,

NOEL OGLIVIE,
Superintendent.

INSPECTOR'S OFFICE.

The work of the inspector's office, under the direction of Mr. W. M. Tobey, Senior Geodetic Engineer is summarized under the following heads:—

1. Refinement and correction of field data.
2. Location of field controls (bases and Laplace points) to control growing errors due to inaccuracies of field work.
3. Progress in the adjustments (including level adjustment).
4. Progress in research to improve methods.
5. Determination of precisions of parts of the triangulation as advisory for new field work
6. Determination of finished data; its necessity to engineers and surveyors.

1. REFINEMENT AND CORRECTION OF FIELD DATA.

The field operations for the current year were confined chiefly (1) to the extension of the bay of Fundy triangulation northwards to meet the Westmorland base near the strait of Northumberland and the Laplace point at Hall's Hill, the northern extremity of such base and (2) to the establishment of a base near the Laplace point Klucksiwi in the Queen Charlotte-Georgia net,

The angle and side equations were tested to see if they were of the required accuracy for primary work, for side equations the test being that the average correction to be given by the adjustment should not be greater than 0.4″.

During the year many descriptions of the markings and locations of observing stations have been received and revised. These are essential to the public in recovering such stations for their use. It is part of the duty of the cataloguer to see that such descriptions are so filed and indexed with other matter as to be readily available. An indexing of all matter *under the name of the place* has given excellent results.

2. LOCATION OF FIELD CONTROLS (BASES AND LAPLACE POINTS)

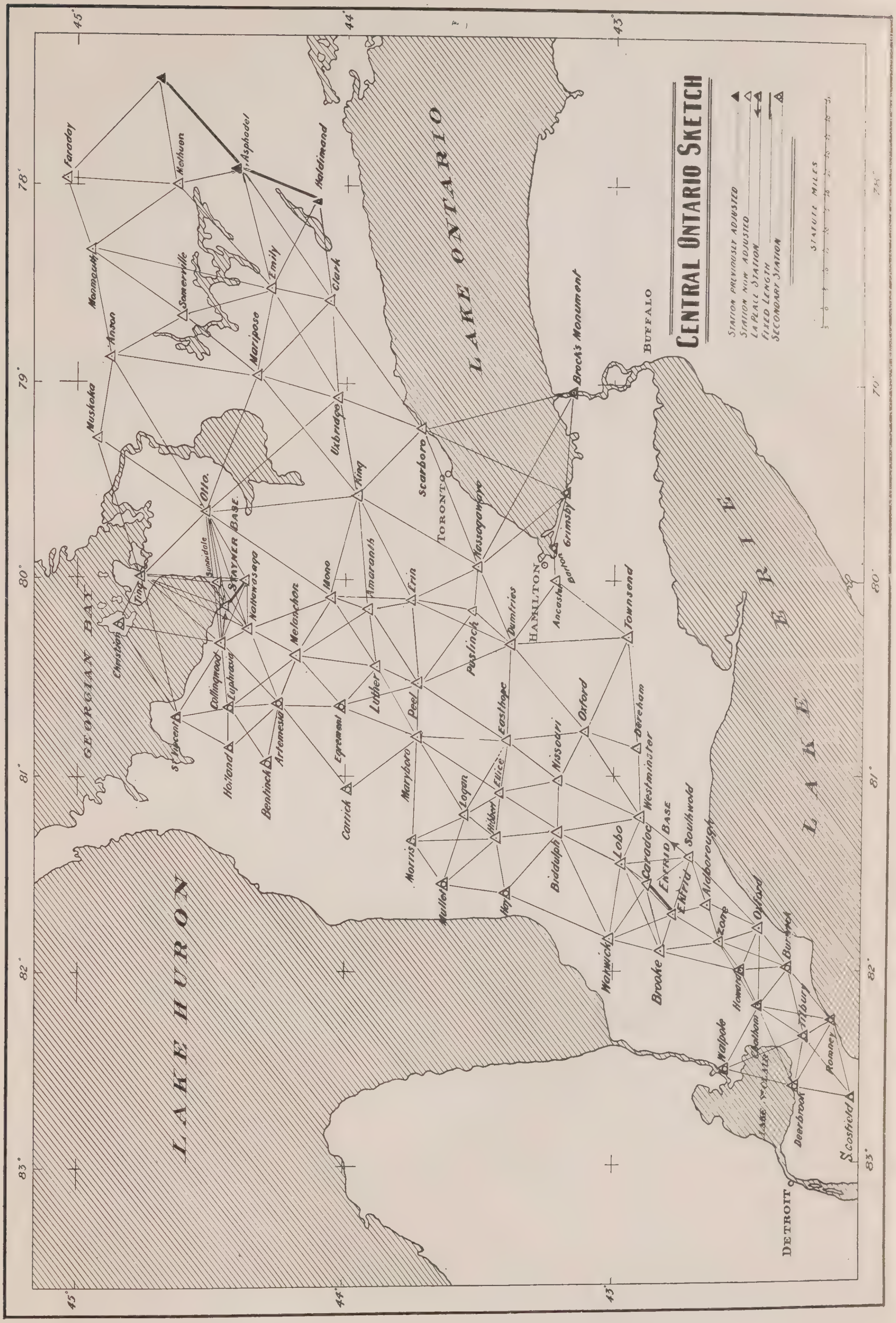
These, as previously mentioned, were located in two portions of the country, viz., at the head of Vancouver island and the head of the bay of Fundy. Considerable difficulty was experienced in the location of the base on Vancouver island, owing to the presence of timber and other growth. As the main source of accumulative error in triangulation seems to lie in the twist or bend and not so much in the scale, it is hoped that the two Laplace points at Klucksiwi on Vancouver island and Hall's Hill will place the triangulation in a strong and reliable position.

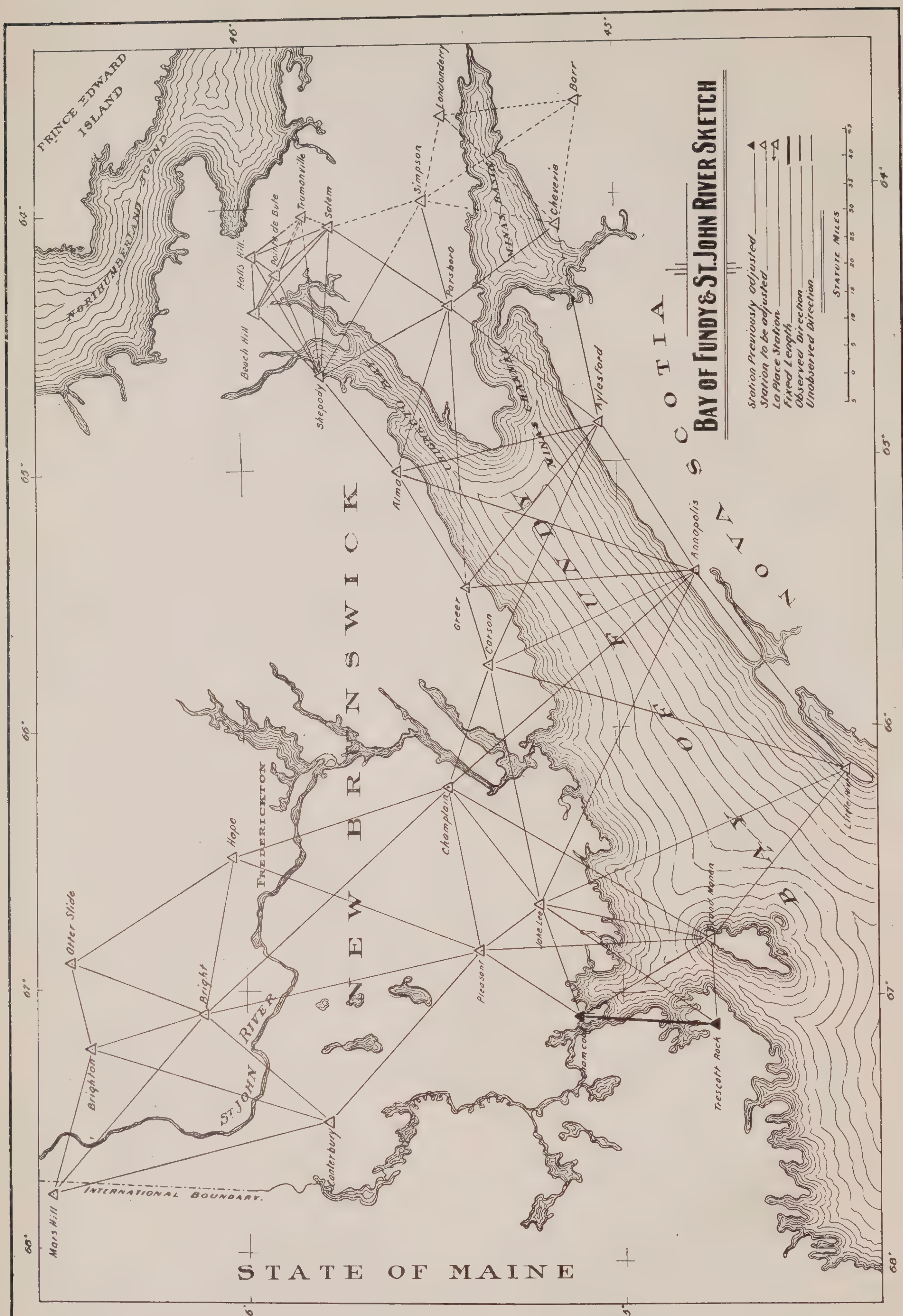
3. PROGRESS IN THE ADJUSTMENT

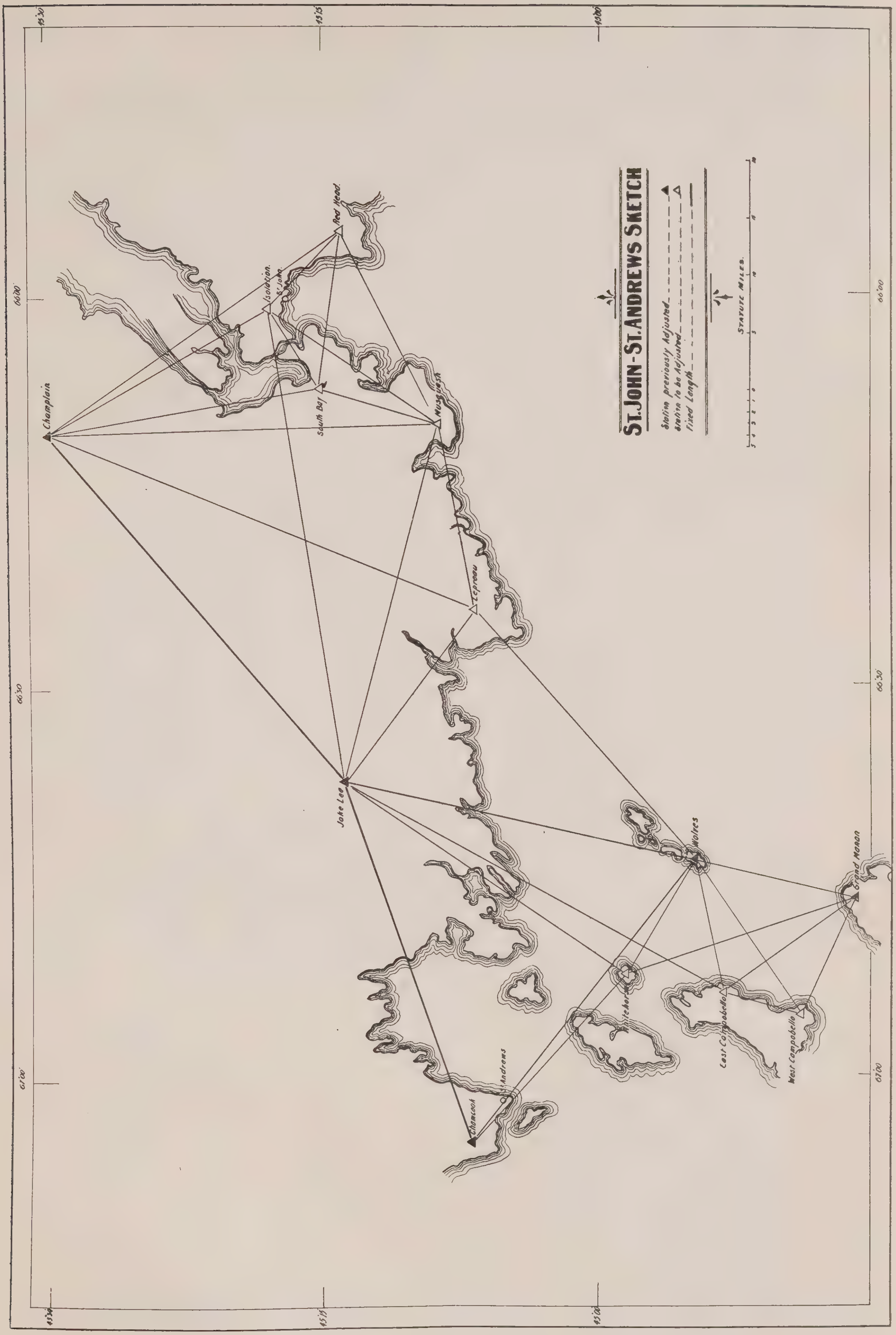
It is evident that, while triangulation could be adjusted for discrepancies of ordinary conditions, as angle and side equation conditions, so as to give out preliminary values, it is *not possible* to determine an adjustment to include culminating effects of twist in azimuth or discrepancy in scale as given by a measured base, until it has been decided as to where and how such twist and scale accumulative errors can be corrected. Thus final values must await the arrival of Laplacian points and base determinations.

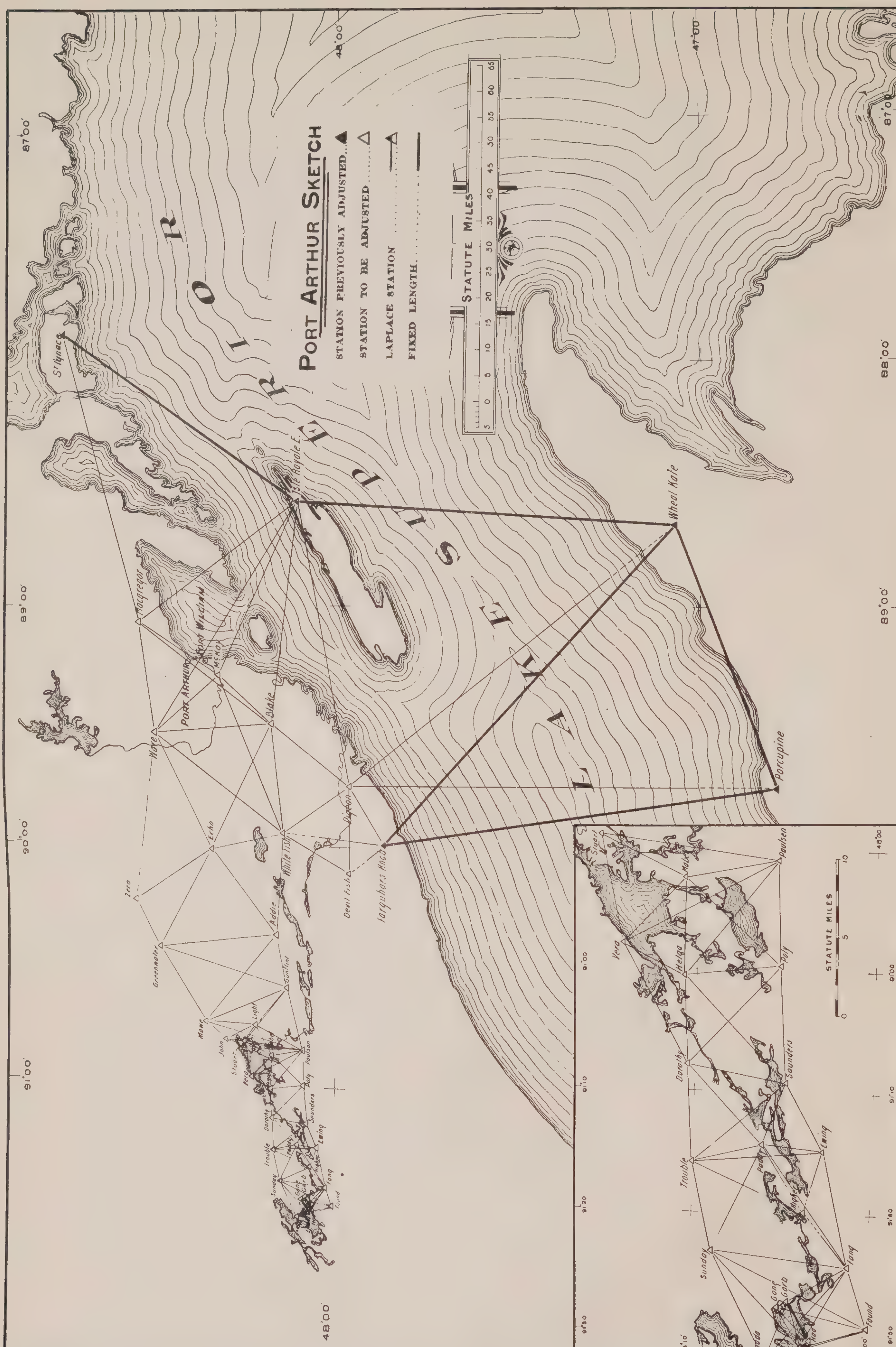
In the primary net shown on page 37 two bases and two Laplace points occur. This is a very large net involving many conditions and satisfactory progress is being made considering the limited number in the office available to work at the adjustment of it.

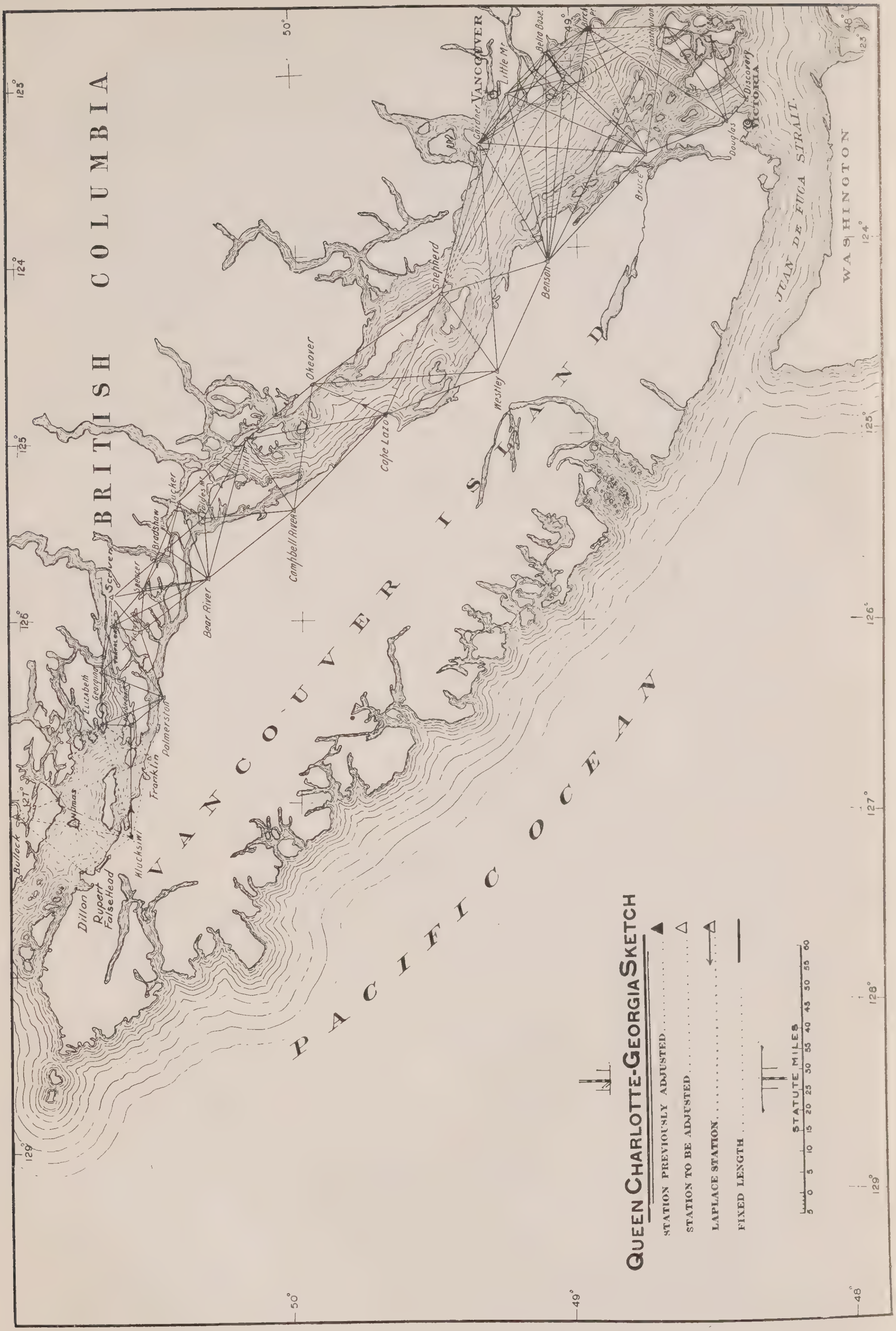
The bay of Fundy net, a primary net as shown on page 38 has one base and two Laplace points, one being situated at Chamcook to eliminate as


CENTRAL ONTARIO SKETCH
Station previously adjusted
Station now adjusted
LaPlace Station
Fixed Length
Secondary Station
Statute Miles
LAKE HURON
GEORGIAN BAY
LAKE ONTARIO
LAKE ERIE
TORONTO
HAMILTON
BUFFALO
DETROIT
STAYNER BASE
EKFRID BASE
Faraday
Methuen
Asphodel
Haldimand
Monmouth
Somerville
Emily
Clark
Anson
Mariposa
Muskoka
Uxbridge
Scarboro
King
Otto
Nassagaweya
Grimsby
Brock's Monument
Barton
Ancaster
Townsend
Sunnidale
Nottawasaga
Tiny
Christian
Mono
Amaranth
Erin
Puslinch
Dumfries
Melancthon
Luther
Peel
Collingwood
Euphrasia
Artemesia
Egremont
St. Vincent
Holland
Bentinck
Carrick
Maryboro
Logan
Ellice
Easthope
Nissouri
Oxford
Dereham
Westminster
Southwold
Hibbert
Morris
Biddulph
Lobo
Caradoc
Ekfrid
Aldborough
Zone
Orford
Hullett
Hay
Warwick
Brooke
Howard
Chatham
Tilbury
Walpole
Romney
Gosfield
45°
44°
43°
78°
79°
80°
81°
82°
83°


BAY OF FUNDY & ST. JOHN RIVER SKETCH
Station Previously adjusted
Station to be adjusted
Lo Place Station
Fixed Length
Observed Direction
Unobserved Direction
STATUTE MILES
PRINCE EDWARD ISLAND
NORTHUMBERLAND SOUND
NEW BRUNSWICK
NOVA SCOTIA
BAY OF FUNDY
MINAS BASIN
MINAS CHANNEL
FREDERICKTON
ST. JOHN RIVER
INTERNATIONAL BOUNDARY
STATE OF MAINE
Londonderry
Barr
Simpson
Trumonville
Salem
Hollis Hill
Pointe de Bute
Beach Hill
Shepody
Parsboro
Cheverie
Aylesford
Alma
Greer
Corson
Annapolis
Champlain
Hope
Otter Slide
Bright
Brighton
Canterbury
Mars Hill
Pleasant
Jone Lee
Grand Manan
Trescott Rock
Little River


St. John - St. Andrews Sketch
Station previously Adjusted
Station to be Adjusted
Fixed Length
Statute Miles
Champlain
Isolation
St. John
Red Head
South Bay
Musquash
Lepreau
Jake Lee
Wolves
Grand Manan
East Campobello
West Campobello
St. Andrews
Chamcook

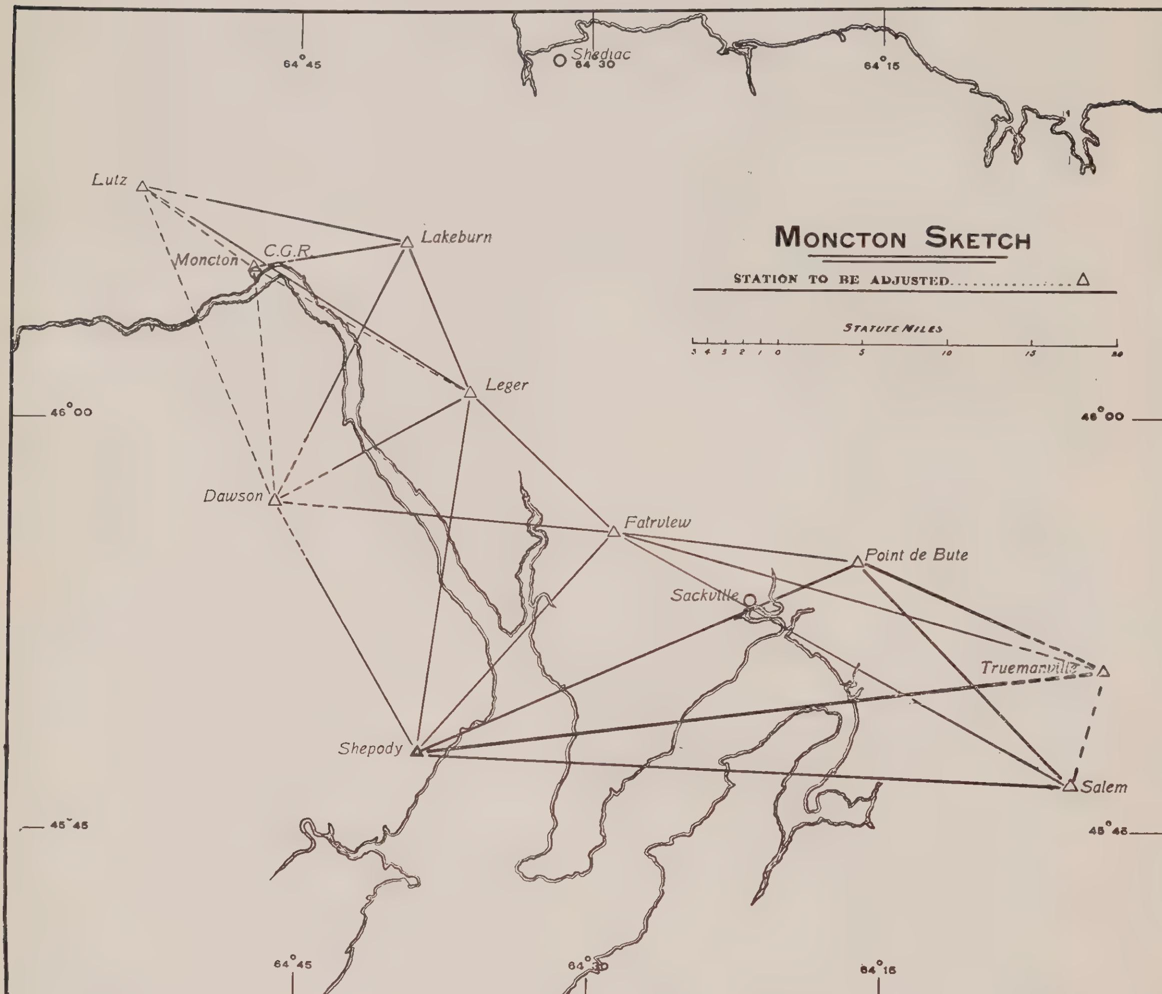

PORT ARTHUR SKETCH
STATION PREVIOUSLY ADJUSTED
STATION TO BE ADJUSTED
LAPLACE STATION
FIXED LENGTH
STATUTE MILES
L A K E S U P E R I O R
St Ignace
Isle Royale E.
Wheal Kate
Porcupine
Macgregor
Port William
Port Arthur
Blake
Wolfe
Echo
Zero
Pigeon
Devil Fish
Farquhars Knob
White Fish
Addie
Greenwater
Gunflint
Mowe
John
Stuart
Vera
Helga
Dorothy
Trouble
Sunday
Paulsen
Poly
Saunders
Ewing
Fong
Found
Gant
Carb
Canada
Emily
87°00'
88°00'
89°00'
90°00'
91°00'
48°00'
47°00'



QUEEN CHARLOTTE-GEORGIA SKETCH
STATION PREVIOUSLY ADJUSTED
STATION TO BE ADJUSTED
LAPLACE STATION
FIXED LENGTH
STATUTE MILES
BRITISH COLUMBIA
VANCOUVER ISLAND
PACIFIC OCEAN
JUAN DE FUCA STRAIT
WASHINGTON
VANCOUVER
VICTORIA

far as possible the twist which may be still inherent in the basic azimuth line Chamcook-Trescott Rock. A portion of this net, as far as station Alma, has been given a preliminary adjustment. But the final adjustment cannot be given until the station Parrsboro is observed.

The secondary net, in the vicinity of St. John, N.B., and along the shore of the bay of Fundy, see page 38, is making satisfactory progress in its preliminary adjustment, an adjustment which is preliminary as it is based on preliminary values of certain points of the bay of Fundy net.



The Port Arthur net, originally on the Lake Survey Datum, is being transferred to the North American Datum and will shortly be placed in such a position. The progress sketch on page 40 illustrates this net.

The British Columbia net, as shown on page 41 has been extended by the incorporation of a base near Klucksiwi. It thus has two bases and one Laplace point.

The city of Moncton, on the Petitcodiac River, will also be able to have its detailed topographic survey with the completion of the location of subsidiary points as shown on this page.

As, by your agreement with the Topographical Surveys, the Reclamation Service and the Dominion Water Power Branches of the Interior Department, the Geodetic Survey of Canada is to be entrusted with the adjustment of the level net, which already extends from the Atlantic to the Pacific and embraces

approximately 25,000 miles, it is evident that extra help will have to be procured to assist in this important work. The adjustment of a level net not only will eliminate such systematic errors as that due to the fact that the earth is not a sphere but a spheroid, so that successive level surfaces are not parallel but situated at different and uneven distances from each other, and which errors will be corrected by what is known as the Orthometric Correction, but it will also reduce the outstanding discrepancies of non-closure of nets, and conflicting or discordant values of the same point.

Thus the adjustment paves the way, by bringing in uniformity of results over the country, for the entrance of one datum which will be known as the Mean Sea Level Datum. In this way all points in a level net will, by their published altitudes, at once give a value above sea level which is not unharmonious with that deduced in other ways by different level routes of the same net.

4. PROGRESS IN RESEARCH TO IMPROVE METHODS

This is a subject about which it is evident a report cannot be made every year. It is, however, one of the greatest importance to the Geodetic Survey. A method may be said to be an improvement on the old when its application saves time and promotes accuracy. Particular mention is here made of the new system of determining geographical positions, on our ellipsoid earth. The basis of this new system is that certain products, represented in brief by π a b sin x tan y can be evaluated as π a b x y. Thus many terms of a series developed by Taylor's Theorem are avoided, thereby saving time and promoting accuracy. It is hoped that the detailed explanations of these formulæ will soon be given in a technical report.

5. DETERMINATION OF THE PRECISIONS OR PROBABLE ACCURACY OF SIDES AND OTHER EXTERNAL PARTS OF THE TRIANGULATION AS ADVISORY FOR NEW FIELD WORK

This is a subject that always needs the care and attention of the office. All realize that the errors of the old triangulation must be running into the new contemplated work.

Hence it may be stated in general terms, that as a guide for the prosecution of new triangulations, beginning on certain sides of the old triangulation, the probable accuracy of the lengths of such sides should be known, as well as that of other parts of the old triangulation. Only by knowing the probable accuracy of these sides can the reconnaissance man have a definite idea of how far he should proceed before a base is required, and only by such knowledge can this office definitely settle the locality of the base or other controls.

6. DETERMINATION OF FINAL DATA AS SUITABLE FOR ENGINEERS, SURVEYORS AND THE GENERAL PUBLIC

The general determination of finished data, data free from clashes and incongruities, depends upon a study of the theory of errors, a theory that has been elaborated by many geodesists of the world, so as to bring about an adjustment of all the data, to give the most probable values. No adjustment will necessarily give the exact values, but only the most probable.

It is therefore necessary to do everything possible to *increase* the probability of the accuracy of such values. This is done by welding or moulding as much of the field data into one and the same net as is compatible with human ability aided by all devices possible to alleviate the burden.

While adjustments could be made of smaller nets, thus entailing far less work and quicker results, yet it is felt that such a process for a geodetic survey, which is primarily to control other surveys, would lessen the reliance that could be placed on these results, and so defeat the great aim of our work. To increase the probability of the accuracy of results of the Geodetic Survey of Canada so that they will be a true aid to other surveys, demands an adjustment of as large nets as possible, with all the data in one simultaneous operation.

Finished data is expected to be furnished very shortly for,

1. Parke–Dusable net (See Sketch on page 45).
2. The survey involving the Fraser River Engineering scheme.
3. The survey having for its object the furnishing of control points of the city of Montreal.
4. Western Ontario net.
5. Bay of Fundy net.
6. St. Andrews–St. John net.

Adjustments of the British Columbia Coastal net and the Port Arthur net will follow afterwards, having already been adjusted in a preliminary sense.

Progress of the Geodetic Survey in British Columbia

W. M. Dennis reports as follows on the work on the coast of British Columbia during the field season of 1918.

With instructions to strengthen the coast triangulation by a station located near Knight inlet, and to locate, tie in, and prepare a base line in the vicinity of Malcolm island, the undersigned left Ottawa on May 8th. However, due to labour troubles in the shipyards of Vancouver, considerable delay was encountered on the repairs to our launch "Metra," so that it was not till June 2 that the party made camp on Malcolm island.

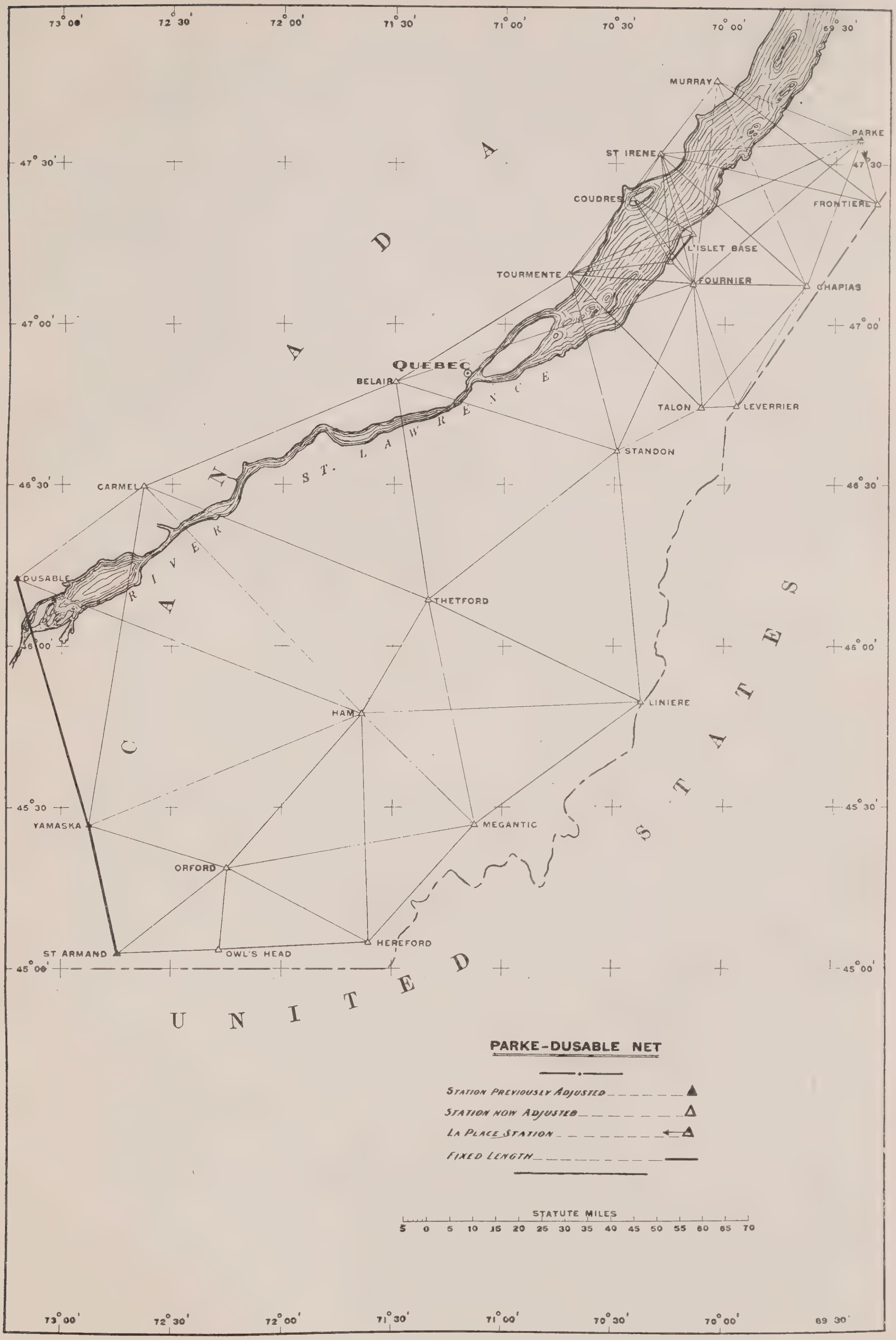
To strengthen the triangulation, a station was located on Mt. Scriven. The work of connecting this station to the chain of triangulation, was carried out by Mr. MacTavish, who will report directly to you on this matter.

When seen from a boat, from any direction, Malcolm island appears to be a fairly level plateau about 300 feet high. For this reason it was chosen, in the office, as the only probable location for a base in this vicinity.

This island is covered with an almost impenetrable undergrowth known as salal. On one occasion it took seven hours to travel a distance of four miles, and on another, five and a half hours to travel two and a half miles. To obtain a view of the country, it was necessary to climb to the top of the highest trees, and as these trees are from 175 to 225 feet high, with a correspondingly large diameter, this work was always difficult and at times dangerous. About the only way of arriving at the top of these trees is by climbing a small one in close proximity to a larger one, which in turn is close to the tree chosen as an outlook. Then by crossing from the smaller to the branches of the larger, one finally, if fortunate, finds himself in the top of the proper tree. It is very essential to mark the route taken from one tree to another, as it is much more difficult to find a way down, omitting the route that ends in a sudden stop, than one would expect. For this reason, it took considerable time to get a comprehensive idea of the topography, and it was finally found that the island was not really a plateau, but was so broken by low ridges that no line could be put through economically which could be measured with the required accuracy.

A good location for a base was discovered on Vancouver island, running southeasterly from Fort Rupert, and although the size of the timber and the amount of salal would make the base rather expensive, it was decided advisable to proceed at once with the preparation.

There was only one possible location for the base, but an expansion and connection to the primary triangulation was obtained, which is quite simple and adequate. The sketch on page 41 shows the primary quadrilateral, Klucksiwi-



73° 00'
72° 30'
72° 00'
71° 30'
71° 00'
70° 30'
70° 00'
69° 30'
47° 30'
47° 00'
46° 30'
46° 00'
45° 30'
45° 00'
CANADA
UNITED STATES
ST. LAWRENCE RIVER
QUEBEC
MURRAY
PARKE
ST IRENE
COUDRES
FRONTIERE
L'ISLET BASE
TOURMENTE
FOURNIER
CHAPIAS
BELAIR
TALON
LEVERRIER
STANDON
CARMEL
DUSABLE
THETFORD
HAM
LINIERE
YAMASKA
MEGANTIC
ORFORD
HEREFORD
ST ARMAND
OWL'S HEAD
PARKE-DUSABLE NET
Station Previously Adjusted
Station now Adjusted
La Place Station
Fixed Length
STATUTE MILES
5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

Shushartie-Robinson-Bullock, with the connection of the base, Fort Rupert-False Head, thereto.

During the time expended on the location of a base line, Mr. McTavish on his first station, Scriven, needed six more men than would be used on his subsequent work, while the preparation of Klucksiwi, the station chosen for the Laplace point, to be occupied by Mr. McDiarmid, gave occupation for the remainder of the party not used on reconnaissance.

On August 1 camp was moved to Fort Rupert, and work on clearing the base begun two days later, the men being obtained from the other parts of the work, with some new men from Vancouver. The chief difficulty encountered was lack of competent labourers. The work was chiefly of the nature of lumbering operations, and as the lumber men paid extremely high wages, it was impossible for the survey to obtain the services of men who knew anything about this business. Of the twelve men who worked on the line, only one, on arrival, could be said to be on speaking terms with an axe.

The work on this base line might be divided into six operations:—

1. Clearing salal and other brush.
2. Felling timber to give a 20-foot sky-line.
3. Instrument work.
4. Clearing the line of all obstructions to measuring operations.
5. Placing posts for the measurement of the base.
6. Measurement of the base.

The total results on the base were obtained in 50 working days with an average of $9\frac{1}{3}$ man-power. It was estimated that about $3\frac{1}{2}$ man-power was expended on the first operation, about 5 man-power on the 2nd, and $\frac{5}{6}$ man-power on the 3rd and 4th. Nothing was done last season on the 5th and 6th operations.

First Operation.—The density of the undergrowth was not uniform. At times it was necessary to place six men on this part of the work. The most competent man in this crew was chosen to cut a narrow passage through the salal, placing pickets on line with others in the rear. The other men worked from this line towards the sides, clearing a space about 40 feet wide. By this method delay through crowding in the head of the line was avoided.

2. The felling was carried out by two crews of three men each, except when the first operation got too far in advance, when some of the men would be taken back to run another saw. These two crews worked a considerable distance apart for safety, two men on each running the saw, while the third prepared the next tree and did the necessary chopping. The forward crew felled enough of the timber to open the line through for instrument work, while the crew following cleared out all side trees which overhung the line, thus opening the line wide enough for the final observations.

As most of the timber is very large cedar, many of the tricks of the lumbermen had to be used, as, for example, the use of spring boards to work at an elevated point where the diameter of the tree made it possible to use a 7-foot saw. This device, uncommon in Eastern Canada, though much used in the West, consists generally of a 5-inch log, 5 feet long, flat on top and squared at one end. A square hole is then chopped into the tree the depth of the bit of an axe and the squared end of the spring board placed in this hole. The axeman then stands on this to chop, saw, or place another spring board higher up to work from. The first attempts were ludicrous, as the knowledge of this method was obtained only by hearsay. Later, however, greater proficiency was attained, which speaks well for the adaptability of the young Canadian. The use of spring boards is shown on page 47. The very large trees, 10 or 11 feet in diameter, could not be handled in this manner, so experiments were made with dynamite. The large trees were mostly hollow shells with walls from six inches to two feet

Using Spring Boards in sawing large cedar trees on Fort Rupert Base line, Vancouver Island.

Clearing the Fort Rupert Base line—Using Spring Boards to get the height where tree is small enough to use cross-cut saws.

thickness, usually of dead wood. There was generally no solid spot where dynamite could be placed, and each tree was a separate problem. In the first few attempts the results were often surprising, as the effect might be practically nil, or, perhaps considerably greater than anticipated. It was found that the location of the charge was the important factor, and after a few experiments very satisfactory results were obtained. Two grades of dynamite were used: 60 per cent, which produces a very quick explosion, and 25 per cent, of which the action is slower. When the charge could be placed in solid material, as green wood, gravel, or water, the 60% dynamite was used, as the shock would be carried farther and large portions of material blown out. When, however, the charge was to be placed in porous wood, as in dead or partially decayed cedar, where the effect of quickness of explosion is lost, due to the resilience of the material around the charge, the more slowly acting 25% with a greater lifting effect, was used. Usually a cedar nine feet in diameter would require four charges each containing from four to six sticks, two being placed on the side towards which the tree is to be felled, and the other two on the opposite side. The location and size of the charge depend chiefly on the shape of the bole of the tree where it is to be cut out.

3. The production of the line of the base was a very simple matter. It was begun from the top of a high tree.

After the line had been opened up for about a half-mile, a large traget was placed on this tree. Throughout the full length of the line this target could be used as a backsight.

Stadia readings were carried forward with the line, and elevations kept up to the instrument each day.

4. The line after the timber is felled is obstructed by windfalls, any of the timber that has fallen across the line, and by old stumps. Very little work has been done on this, except where the line was used as a trail.

It has not yet been decided to what extent this line must be cleared out to allow for the careful handling of the invar tapes, as well as accurate measurement of the base.

Operations five and six will be completed next season.

With regard to the resources of this district, as seen by the casual observer, fish and lumber seem to be the most valuable assets. In the vicinity of Fort Rupert considerable money is taken from these industries both by corporations and by individual endeavour.

There is considerable outcrop of coal along the beach near Suquash, but only one attempt seems to have been made to commercialize this, and this attempt is evidently in its infancy.

The coast of British Columbia should be a mecca for the tourist who has time to stop in one place and see what nature has to offer. The inland passage makes travel inexpensive, as very small launches are safe in good weather at all except three points. Off this passage, innumerable narrow channels, from one to three miles wide, wind their way between the mountains often for distances of more than fifty miles. These mountains with their scenery, their varied fauna, and flora, would be found a paradise by the nature lover, the artist, the mountaineer and, in the game season, by the sportsman. The Swiss knows and is proud of the magnificent scenery of his own country; why not the Canadian?

Observing on British Columbia Coast.

W. H. MacTavish, Geodetic Engineer, submits the following summary report on the observing along the British Columbia Coast during the field season of 1918.

The observing was carried on in the vicinity of Alert bay, about 200 miles north of the city of Vancouver, the object of the work being to strengthen the net in this particular locality. To this end, a station was established on mount

Scriven at the head of Call creek and the necessary angular measurements made from there. In all, five primary stations were occupied. These were Scriven, Bradshaw, Bear River, Victory and Georgina.

Considerable time was lost at the beginning of the season on account of two lines not being opened up. Weather conditions during the months of June and July were as satisfactory as might be expected, but in the month of August not a single observation was taken until the 28th on account of the prevalence of fog. During this month, twenty-three unsuccessful attempts were made to observe. Until August 29th, only two stations had been occupied, while at September 7th five stations had been occupied. This fact is surely evidence that the observer's progress is governed to a very great extent by weather conditions.

City Triangulation.

C. A. Bigger, Assistant Superintendent, makes the following report of the work done during the season of 1918 in connection with City Triangulation.

On July 30 work having for its object the connection of the city of Toronto with the adjacent primary triangulation of the Geodetic Survey was resumed and continued until October 27. Owing to the absence of skilled assistants overseas, the writer did all the instrument work himself, and, on account of the small sum available for work of this nature, only two assistants were employed.

The transit lines north and west of the city were completed and the preliminary determinations of the distances from point to point were made. Owing to the prevalence of dense smoke over and in the vicinity of the city, progress was intermittent and slow. The absence of adequate transport facilities was also found to retard the work very materially. Where work was found to be impossible of one section of the survey, a large portion of the best part of that day was lost in moving to another section where work was of a nature that could be carried on during poor visibility.

Permanent reference monuments have been placed at convenient points along the transit lines to the east of the city.

When the writer was planning the system of survey to be adopted it was considered that both speed and accuracy are essential; it was also borne in mind that some permanent beneficial results should be gained from the survey. From the standpoint of the Geodetic Survey of Canada, the work would be sufficient if ample data were secured to enable the adjusting office to connect the city of Toronto with the Geodetic Triangulation. Owing to the size of the city this of itself constituted a fairly extensive survey.

On this account it was decided that in the public interest and as a matter of economic expenditure of public money it is essential that permanent reference monuments be left for the use of the city and surrounding municipalities; especially as the city of Toronto consented to furnish the materials and labour connected with their construction.

This survey had its origin in 1907 when the writer was instructed to make a complete triangulation of the city of Toronto similar to that of the city of New York completed during that year by the United States Coast and Geodetic Survey. Owing to the many imperative demands for primary triangulation, the writer was unable to train assistants rapidly enough to keep pace with the work—and the survey of the city of Toronto remained in abeyance temporarily.

A skeleton map of the city oriented with the Geodetic Survey was deemed a preliminary requisite. The work of securing the data for a map of that nature was undertaken by the writer when opportunity offered without interfering

with the progress of the Geodetic Survey, at that time being carried on at intervals, from the Atlantic to the Pacific ocean.

The data referred to are secured by means of measured transit lines extending around the city, and angles therefrom to various points throughout the city and also to primary stations of the Geodetic Survey. This work has been carried on in part with one, and, at most, two assistants so that the cost has been trivial.

Before commencing the field work a standard distance of ten Gunters chains—six hundred and sixty feet—was carefully measured on an artificial stone pavement and copper bolts with small pin holes in their centres were leaded into drill holes in the pavement as terminal points. This distance was transferred to the tops of wooden posts, twenty-four inches high, set a few inches north of the bolts—a transit placed sixty feet south of the terminal bolts at right angles to the line of measurement between the bolts was used for this purpose.

The assistants who were employed for the purpose of making all measurements in the field were then instructed to measure the distance between these posts in both directions until consecutive measurements, and measurements on different days under different conditions of temperature and wind could be measured with an accuracy easily within the limit set.

The temperature of the tape during the progress of the work was noted many times and the mean reading throughout each ten chains accepted. An open thermometer was attached to the tape near the front end, for this purpose.

The method of measurement adopted refers the distances measured in the field, to the standard, without any possibility of discrepancies other than the ordinary errors inseparable from all mechanical operations. As the work progressed in the field, the degree of accuracy decided upon, viz., one inch in one mile, was easily attained. This does not mean that there may be three inches in three miles. All errors in measurements made with equal care are expected to be compensatory. The Toronto work during the season of 1918 was no exception to this rule.

All transit lines were projected during good seeing and not less that two sets of observations were made at each station. All angles were measured by repetition, each angle being repeated eight times.

Azimuth observations were made at six stations.

The azimuth observations were made by the repetition method—three pointings on the star and mark with clamp right, followed by three pointings clamp left constituting a set, and six sets a determination. The following record is a fair criterion of the degree of precision attained. The instrument used throughout this work is a four and one half inch Cooke transit of a special design by the writer.

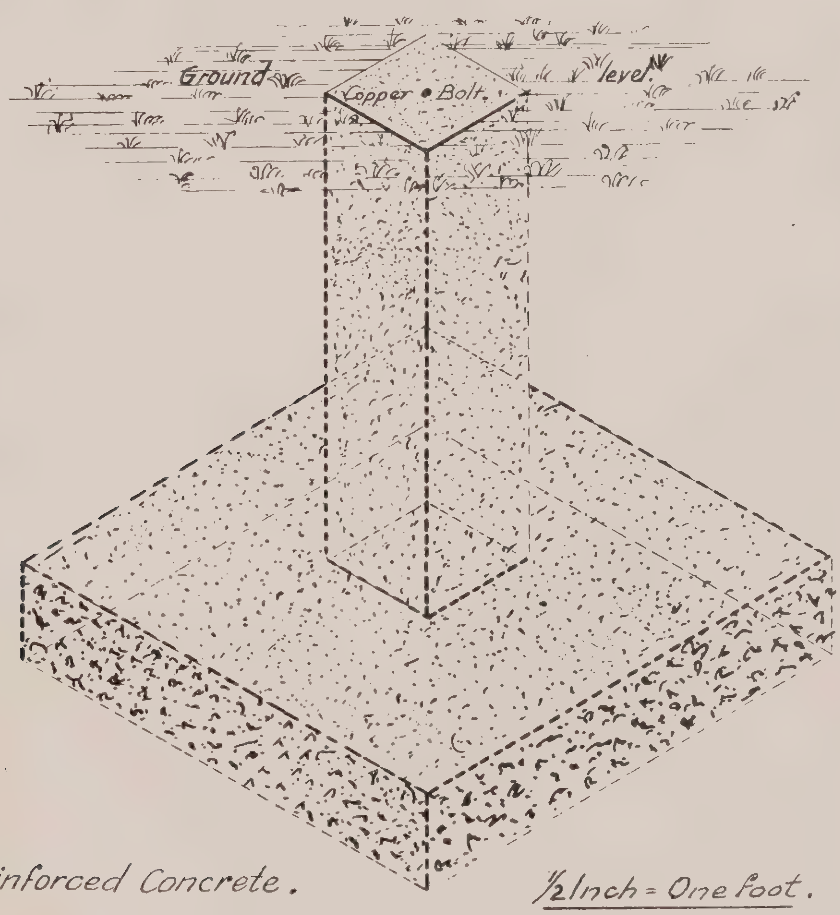
Hour.	Circle reading	
	A. Vernier.	B. Vernier.
h. m. s.		
16 39 11		
40 36	0° 02′ 00″	180° 02′ 30″
42 05		
45 53		
46 33		
47 44	252° 02′ 30″	70° 03′ 15″
16 43 37	Mean Angle	342° 00′ 06″·3

Resultant Azimuth = 343° 09′ 11″·4. Latitude = 43° 38′ 33″. Chronometer slow 1^{m} 51^{s}·4.

The six determinations at this station are as follows:—

Set.	Azimuth.	V.
1	343° 09′ 11″·4	−1″·8
2	07″·5	2″·1
3	04″·6	5″·0
4	10″·8	−1″·2
5	17″·8	−8″·2
6	05″·4	4″·2
	Mean = 343° 09′ 09″·6	

The theoretic probable error of the above determination is 1″·9, the large probable error is due to the apparent inaccuracy of the fifth set. The observer is subject to two adverse conditions in making azimuth observations by this method, viz., instability of the instrument and the tendency to use the wrong tangent when making pointings. Discarding observations such as the above is dangerous, as with small instruments large errors may occur on both sides of the arithmetic mean. The writer has not yet accumulated sufficient data with that particular instrument, to formulate any definite rule for discarding observations.



Standard Reference Monument for City Triangulation
Geodetic Survey of Canada.

In New York city the survey now used by the civic officials is a survey along the streets, consisting of a series of offset lines of which all the angles and distances have been measured. These surveys are of course controlled by the triangulation stations.

During the progress of the work in 1918 a wooded valley of a river was encountered—the clearing of a line of sight through the tree-tops was very tiresome and expensive. As the work for the early part of this season crosses three large river valleys, a reconnaissance was made during the winter when the absence of leaves could be taken advantage of. Triangulations across these valleys were laid out utilizing gaps through the tree-tops, but their angles must be measured in the early spring or much extra expense will be incurred. The balance of the work around the city of Toronto can be finished in about eight weeks.

In conclusion the writer wishes to express his appreciation of the courtesy—and readiness to assist in every way—of the officials of the city of Toronto. The thanks of the Department are especially due the City Surveyor, Mr. Tracy D. Le May, who with his motor assisted the writer in making many long journeys over the work which would otherwise have been tedious and laborious. Acknowledgments are also due that Official for the use of his office and draughting-table.

OTTAWA,

March 28, 1919.

TRIANGULATION IN QUEBEC AND MARITIME PROVINCES

J. L. Rannie, Supervisor of Triangulation in Quebec and Maritime provinces, makes the following report of operations in 1918.

LOWER ST. LAWRENCE DISTRICT

One party, in charge of Geodetic Engineer L. O. Brown, continued the observing of horizontal angles in the triangulation system along the St. Lawrence River below Rivière du Loup, Que. The operations in this section have been the result of requests for geographic positions by the Department of the Naval Service, who require control surveys for their hydrographic charting as far down the river as Anticosti island.

Some reconnaissance surveys were made by the writer below Tadousac, Que., to provide work ahead of Mr. Brown's party.

NEW BRUNSWICK

A secondary triangulation party, in charge of Geodetic Engineer H. F. J. Lambart, worked along the bay of Fundy from St. John, N.B., to Passamaquoddy bay, locating lighthouses, church spires and other points for the use of the Geological Survey and Department of the Naval Service, and co-operated with the United States Coast and Geodetic Survey.

A small secondary scheme was laid out and partly observed by the undersigned from the bay of Fundy to Moncton, N.B., to locate points for the use of the Geological Survey.

A primary observing party, in charge of Geodetic Engineer C. H. Brabazon, commenced operations on the north side of the bay of Fundy and worked around the head of the bay into Nova Scotia, progressing towards Halifax and Cape Breton Island.

NOVA SCOTIA

A reconnaissance party in charge of Professor L. B. Stewart, of Toronto University, continued the triangulation scheme from the vicinity of Truro, N.S., to Halifax, as requested by the Militia Department, and also projected a scheme part way from Truro towards Sydney, C.B.

A tower building party, in charge of Assistant N. E. Kelly, built towers and prepared stations ahead of the party in charge of C. H. Brabazon, reaching almost to the vicinity of Halifax.

LENGTH OF SEASON

On account of the high prices of all items of expenditure, the appropriations provided only a length of season from May 20 to September 25.

INSPECTION

Noel Ogilvie the Superintendent of the Geodetic Survey was accompanied by the undersigned on an inspection trip on the St. Lawrence river, through parts of Nova Scotia and New Brunswick and along the north side of the bay of Fundy.

RECOMMENDATION

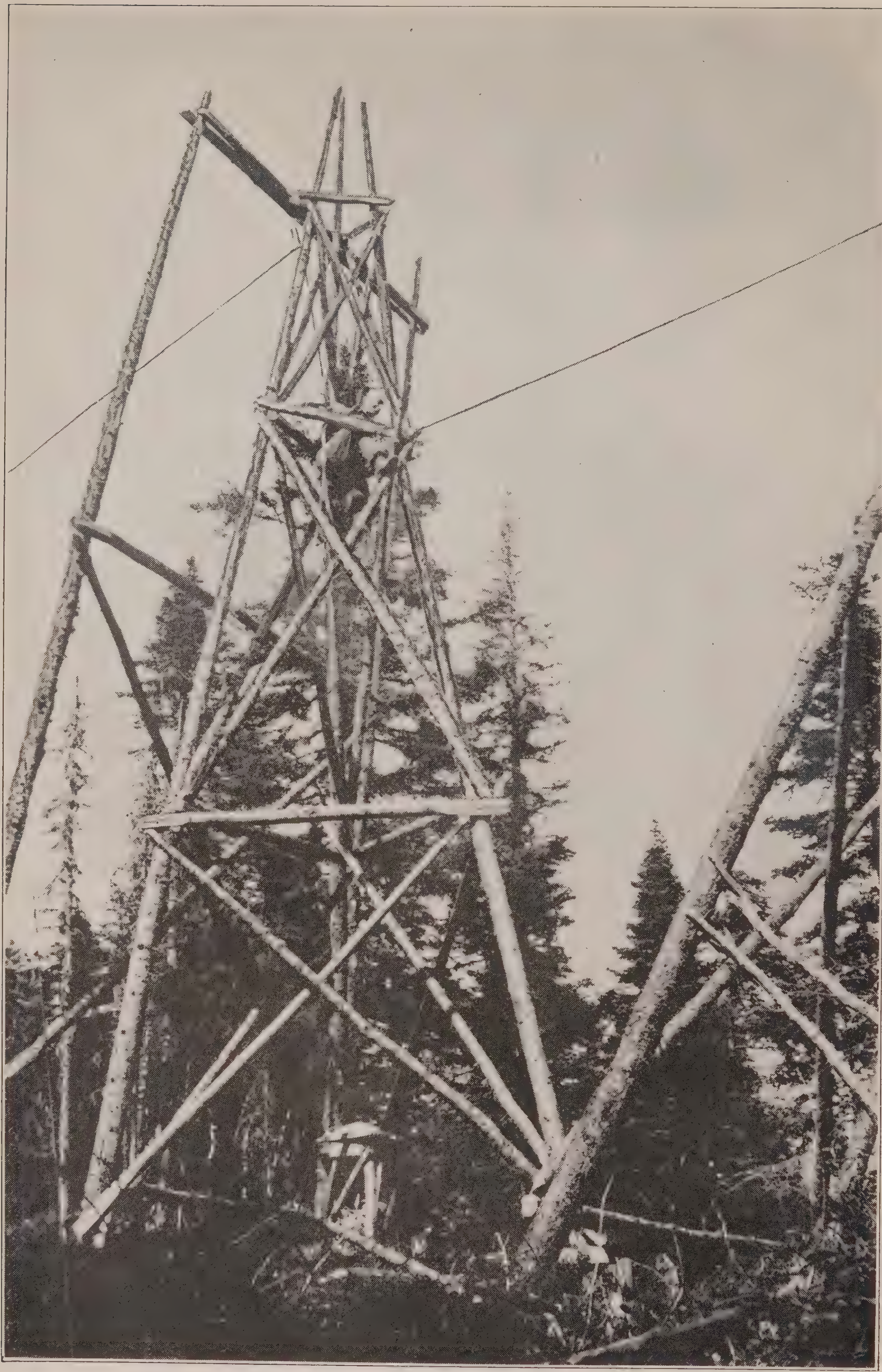
In 1918 the writer was provided with a Ford runabout equiped with a box on the back for carrying baggage and instruments. The great economy and convenience of employing automobiles and trucks in suitable country was amply demonstrated.

The four parties in New Bruwnsick and Nova Scotia were all delayed at various times through difficulties in obtaining transport, while the prices charged for the hire of horses and automobiles were very high. Under these considerations and also that of increased speed in moving from place to place, the use of automobiles and motor trucks for all parties in Nova Scotia cannot be too strongly recommended.

Progress of Primary Triangulation in Eastern Quebec

Lindsay O. Brown, Geodetic Engineer, reports on the triangulation done in Eastern Quebec, in the vicinity of the St. Lawrence river as follows:

The work in this section was carried on by a party of thirteen men. These were an observer, a recorder and a cook; also five lightkeepers, each with a helper. The lightkeepers moved from station to station at the signal of the observer. The Reconnaissance had been done previously and the stations partly prepared, though vistas through the woods on certain hills had not been cut. As the lightkeepers generally preceded the observer on the stations, this work was done by them where possible. On two occasions one of the lightkeepers dispensed with the services of his helper, thus freeing the latter who took charge of a light. In the greater number of cases, however, owing to the isolation of the stations it was impracticable for a lightkeeper to attempt his work without an assistant. It was found necessary at one station, Citadel, to build a tower of thirty-two feet in order to see over a near-by wooded hill. The framing of this was done by the observer, recorder and one lightkeeper, but they had the assistance of the cook for a few hours while raising it.



Rough and Ready Tower Building in Eastern Quebec for sighting over local timber.

Both the tripod, and the outer tower carrying the observer's platform were built of timber obtained from the hill on which the tower was built. As there was very little dry timber on the hill, the whole structure was composed of green. The tripod was built first. Two timbers were laid on the ground, and joined by cross braces and diagonals. The side thus formed was raised by poles, and guyed in an almost vertical position. One man climbed this frame, and by means of a rope raised the top of the third leg, while the men on the ground lifted the bottom end into position. The two remaining bottom horizontals were nailed in place; then the two horizontals at the top of the first bent. The guy ropes were now partially loosened, and the side which had been guyed allowed to sag until the structure was vertical. All the remaining diagonals were now added, beginning at the bottom. After that, the two opposite sides of the outer tower were partially framed, some of the braces of the top bents being left off in order to keep down weight. A man now climbed the tripod, which had been guyed, and pulled on a rope attached to the top of the tower frame, while the other men lifted with poles. When the frame was lifted to a vertical position it was guyed. The opposite side was raised in the same way. Then the horizontals connecting these two sides were put in place. By tightening and loosening the various guys the structure was exactly plumbed, so that the diagonal braces could be nailed in position. See illustration page 54.

Three primary and four secondary stations were occupied by the observer. The main triangulation scheme was carried on by means of the primary stations, while the secondary stations were used in order to see certain villages—also lighthouses not visible from the more distant primary stations. On an average, five lighthouses were observed from each secondary station, the location of these being required for the use of the Department of the Naval Service. An average of nine church spires were also observed from each station. These, being visible from all the surrounding country, served to locate the villages. This information was for the use of the Chief Geographer, for correcting maps. In this way two churches were observed from four stations, one from three stations, seven from two stations, and ten from one; while two lighthouses were observed from three stations, four from two stations, and eleven from one. When the Geodetic stations on the north side of the St. Lawrence river are occupied, nearly all of these villages and lighthouses will be thoroughly located, together with many more of each.

Progress at St. John, N.B. and Along the Bay of Fundy to Passamaquoddy Bay

Geodetic Engineer, H. F. J. Lambart reports as follows on the triangulation system at St. John, N.B., and along the bay of Fundy to Passamaquoddy bay.—

Under instructions from the Superintendent, work was commenced on a system of secondary triangulation in the city of St. John, N.B., including the prominent points and headlands of the harbour.

Work commenced on June 13 with the reconnaisance, followed by the establishing of the stations and finally followed by the instrumental work.

The season's work subsequently resolved itself into an expansion southward from the fringe of the primary system—paralleling the coast some 25 miles inland—by a system of smaller quadrilaterals, from the city of St. John, Westward, to the Passamaquoddy bay.

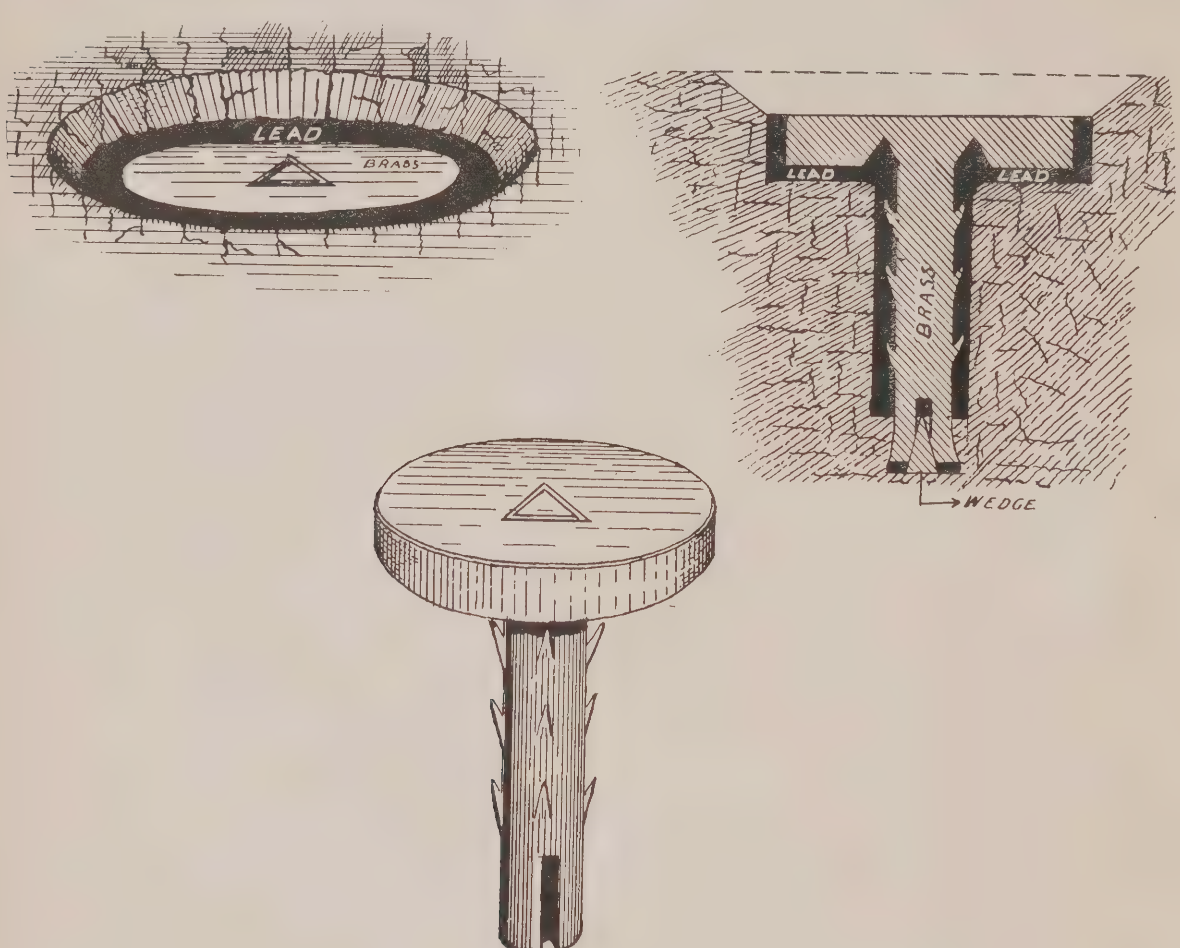
Reconnaisance.

Reconnaisance was carried out by means of the plane-table on to which was tacked the best map of the district procurable, and of large enough scale to show the most prominent features of the country such as spot elevations, roads,

villages, farms, etc., as well as the coast line showing the lighthouses, etc. With this spread out before one it was never difficult to get a very good orientation of the table even when known signals were not to be had, by recognizing prominent features, or as the last resort by the use of the compass. With a few needles and an open faced alidade the working out of the triangulation scheme together with alternative schemes became not a difficult matter in most cases.

ESTABLISHING STATIONS

All stations extablished were of a very permanent nature with the exception of a single instance where it was found almost impossible to get down to any form of solid formation. The point above referred to was West Campobello on the west end of Campobello island situated amongst the outer islands of the



Triangulation Station Mark showing method of Leading into the solid rock.

Passamaquoddy bay. The station points were drilled holes about 8″ deep into which were sunk brass bolts capped by a round tablet, (the one in common use in the service) and secured by splitting the lower end of the bolt which is expanded tightly against the sides of the drilled hole by a brass wedge which is driven up through the centre of the bolt as the bolt itself is driven down, until the under side of the tablet rests upon the surface of the counter sunk impression made to receive it. This method has not proven to be absolutely safe against the depredations of inquisitive persons and it is suggested that in future a more perfect bond be contrived between the rock and the bolt. The following is a description of such a device.

With the present form of construction of bolt and tablet, notch the sides of the bolt making a number of lips pointing upwards; then drill a hole leaving a clearance of 1/4 inch around the bolt for two-thirds the length of the bolt; at the bottom of this the hole is to be continued the remaining third just large enough to permit of the insertion of the bolt. The upper surface of the rock is then chiselled so as to counter sink the tablet below the general surface an inch or more making it impossible to get a pry under the lip of the tablet. With the hole and surrounding rock perfectly dry molten lead is then poured in filling around the shank of the bolt and up flush with the top of the tablet. This whole operation may at first occupy some little time but with a little practice and with proper rock drills, chisels and rock hammer it is not difficult and need not take up much time. What has been given above is the result of some observations made during the past summer with some few experiments. There is no doubt however that the ordinary deeply sunk straight copper bolt leaded, is the more permanent, but where it is desirable to have a little more showing on the surface to facilitate the finding of the point there is no doubt that the tablet is preferable. The slight depression in the rock caused by the countersinking of the head of the tablet acts in a way as a safeguard, as it becomes quickly filled in by sand or dirt and is obscured from view and would attract no attention from the uninitiated.

Example of Field Book Record   Horizontal Directions   Repetition Method

Station Whitehorse..   Observer H. F. J. Lambart.   Instrument. 811. (Berger).   Date August 19, 1918.

Objects Observed	Time	Direct or Reverse	°	'		Verniers A	Verniers B	Mean	Remarks
Chamcook	6.58		00	00		00	$\overline{10}$	05	6 128-08-45
Jake Lee		1/D	81	21		27			81-21-27·5
Jake Lee		3/D3/R	128	08		40	50	45	- 1·1 Correction
Chamcook		3/R3/D	00	00		10	00	-05	26·4 Corrected angle
								45 total mean	
Jake Lee			00	00		00	00	·00	6 158-21-32·5
Wolves		1/D	86	23		35			86-23-35·4
Wolves		3/D3/R	158	21		30	40	35	- 1·1 Correction
Jake Lee		3/R3/D	00	00		10	00	-05	34·2 Corrected angle
								32·5 total mean	
Wolves			00	00		10	00	-05	6 252-45-42·5
Grand Manan		1/D	42	07		37			42-07-37·1
Grand Manan		3/D3/R	252	45		40	50	45	- 1·1 Correction
Wolves		3/R3/D	00	00		00	00	00	36·0 Corrected angle
								42·5 total mean	
Grand Manan			00	00		00	00	·00	6 180-44-27·5
Chamcook		1/D	150	07		20			150-07-24·6
Chamcook		3/D3/R	180	44		10	20	15	- 1·2 Correction
Grand Manan		3/R3/D	·00	00		20	30	25	23·4 Corrected angle
								27·5 total mean	
									360-00-04·6
									-04·6 Total correction
									360-00-00

N. B.
$\overline{10}$ = Form of recording adopted instead of recording 359-59-50
The second line in each set is the reading of the "A" vernier after the first repetition giving a close approximation of the angle being read.

$\frac{04\cdot6}{1\cdot1}$ Correction per angle.

1/D = One repetition to telescope direct.
3/D3/R = Six repetitions, 3 with telescope direct plus 3 with telescope reversed.
Total Mean = Mean of verniers after sixth repetition. Algebraic mean of verniers at commencement and closing of set.

Form used for recording Angle Readings, Repetition Method.

Angle Readings

The angle readings were made with a $6\frac{1}{4}$-inch Berger reading to ten seconds The usual repetition method was employed, each angle being measured six times followed immediately by six repetitions of the explement.

The programme consists in first setting A and B verniers at zero, or nearly so, and pointing on the initial station with telescope direct, make three repetitions of this angle, then with telescope reversed the same angle is again read three times. At this juncture the both verniers are read. The explement of the angle is now read three times with telescope (as it stands) reversed; then after transiting the telescope the explement is again read three times, ending the complete series on the initial station with telescope direct. If the work has been done without the accumulation of any pointing or instrumental errors the verniers should be reading as they were at the outset. The closing, the average of the two verniers, should not be allowed to be greater than 15 seconds. This should permit, generally speaking, of an error not larger than $2\frac{1}{2}$ to 3 seconds to the angle for the horizon closing and with this degree of accuracy on sides not shorter than three or four miles, an average triangular closure of about 3 seconds should be secured. An example of the recording of a complete set in the field book is shown on page 57.

CO-OPERATION WITH UNITED STATES COAST AND GEODETIC SURVEY

It was gratifying while engaged in work in the International Boundary waters outside of the town of St. Andrews, at the head of Passamaquoddy bay, to have been of assistance to wire drag parties from the Coast and Geodetic Survey of the United States, making accurate and final soundings of the bay and the channels amongst the outer islands as far out as Grand Manan.

All our work in these waters was done from a large fishing schooner chartered for the purpose from Welshpool, on Campobello island. Having completed the reconnaissance from the mainland and with suggestions supplied by Mr. Hawley (in charge of Party No. 2, U. S. C. and G. S.), the rest of the work was proceeded with from our chartered schooner direct. This work consisted in establishing geodetic stations on Whitehorse island)—a desolate, barren, gull island, east of Campobello island—two stations on Campobello island, one at the eastern end and one at the western, one station on the South West Wolves—which was found to be an old point of the United States Coast and Geodetic Survey, and which was redrilled and a tablet fixed in place—and finally the occupation of Grand Manan primary point itself.

A point of historical interest arose when investigating the land owned at East and West Campobello. The original grant, which is about 10,000 acres (which the island is supposed to contain) came from the British Crown about the time of the conquest of Canada, 1763, to the antecedents of Admiral Owen, who personally came into possession in 1835. The original Admiralty charts of the bay were executed by this able officer, many of whose original marks are to be found; also ruins of the buildings he once occupied. It was sold to the present owners, The Campobello Island Co. of Boston, in 1878.

A list of stations occupied follows:—

	Station.	How Marked.	Remarks.
Primary...	Carson	Copper bolt.	
" ..	Jake Lee	"	
" ..	Champlain	"	
" ..	Chamcook	"	Eccent. Sta. Occupied that established by McCallum in 1909.
" ..	Grand Manan	Copper bolt	Canadian Point occupied.
" ..	Wolves	Drilled hole replaced by tablet	U.S.C. & G.S. point.
Secondary.	Red Head	Tablet.	
" ..	Isolation	"	
" ..	Musquash	"	
" ..	South Bay	"	
" ..	Lepreau	"	
" ..	Whitehorse	"	
" ..	East Campobello	"	
" ..	West Campobello	Tablet set in boulder set over point.	
Tertiary...	Fort Howe	Tablet.	
" ..	St. John	Concrete pier	Astronomical station.
" ..	Catholic Cathedral Spire.		
" ..	Trinity Church Spire.		
" ..	Atlantic Sugar Refinery Stack.		
" ..	Martello Tower at West St. John.		
" ..	Lighthouse on Partridge Island, St. John Harbour.		
" ..	Lepreau Lighthouse.		
" ..	Lepreau Lighthouse Power Station Stack.		
" ..	Swallow Tail Lighthouse on Grand Manan Island.		
" ..	Head Harbour Lighthouse.		
" ..	Mascabin Lighthouse.		
" ..	Bliss Island Lighthouse.		
" ..	Pea Point Lighthouse.		

Progress in Reconnaissance in Nova Scotia

Professor Louis B. Stewart submits the following report on the reconnaissance carried on in Nova Scotia during the summer of 1918.

In May last instructions were received to proceed to Nova Scotia and make a reconnaissance with the object of connecting the main chain of triangulation that follows the bay of Fundy and Minas basin with stations to be established near Halifax, and then to extend the reconnaissance of the main chain easterly to Prince Edward Island and Cape Breton. A preliminary reconnaissance of the latter region had already been made by H. P. Moulton, Geodetic Engineer.

The writer left Ottawa, accompanied by Mr. Rose as assistant, on May 22 and reached Truro the following day. The first step was to visit the established stations in the neighbourhood, from which the triangulation might be extended southward. At Barr we measured a short base line and triangulated the distances to a number of points, so as to from a scale of distance depending on visibility. In this way we established with considerable accuracy the position of Taggart Hill, which we afterwards selected as the site of a primary station.

On June 15 we went to Halifax, and there found the most suitable point for a station in the vicinity to be Geizer Hill, to the northwest of the city, as it is the highest point to be seen for many miles in all directions, and commands a good view of the city and harbour, and of several surrounding points that will serve for secondary stations.

The view form Geizer to Barr, however, was cut off by an intervening hill. The height of Geizer Hill had been well determined, and a vertical angle measured there gave the height of the intervening hill. We had also found the height of the ground at Barr by the aneroid and a computation based upon these heights and the mutual distances of the three points showed that the extreme points should be intervisible. A light shown at Geizer, however, could not be seen from a tree-top at Barr.

The heights of the intervening hill and Barr were then redetermined. A base line was measured on the railway track near Grand Lake station, from which the height of the former point was found, agreeing closely with that given by the vertical angle observed at Geizer. Aneroid readings were then taken at Shubenacadie and Barr—two at Shubenacadie and intermediate reading at Barr—motoring quickly from one point to the other, so as to make the readings as nearly simultaneous as possible. This reduced the height of Barr as previously found, by over 60 feet and brought it into agreement with the height found by a vertical angle observed there. This experience emphasizes the known fact that barometric heights should be accepted with caution, and shows the value of vertical angles as checks. We thus found that a tower 70 feet high at Barr and one 50 feet high at Geizer should be intervisible.

After making careful examination of the country westerly as far as a line drawn from Windsor to Chester, we finally placed a station at Ardois, which lies northeasterly from Ellershouse. This forms a quadrilateral with Cheverie, Londonderry, and Barr; and another with Barr, Geizer, and Taggart—above referred to. We also established the secondary stations Dartmouth, Sambro, and Devil's island, which are all visible from Geizer, and the first two from Taggart.

It was now necessary to find the best way to reach Taggart. As it lies about five miles northeasterly from Waverley, the nearest point on the railway, we first tried to reach it by walking across country from there, but found that route to be very rough, and decided that it is impracticable for the conveyance of instruments and camp outfit. The following day therefore we drove about seven miles from Waverley along the Guysborough Road to where a bush road turns south, which we followed for a mile and a half to a shanty owned by George Chapman, a hunter and guide, who conducted us by foot-paths known only to himself, to Taggart Hill, about five miles farther. This hill is a bare rock, which, together with its height, distinguishes it from the surrounding hills. It rises abruptly from the southwesterly shore of a small lake—Red Trout Lake. On its summit stands a moss-grown cairn, which points to its having been used for some purpose in the past. According to Chapman it has been used as a signal station by the military authorities. Chapman's services should be of great value to the observing party when they occupy that station.

With everyone kept on the qui vive by reports of German submarines operating in Canadian waters it was not surprising that we should repeat the experience of other members of the Survey staff, and find ourselves regarded with suspicion by the people among whom we were working. This was troublesome on two occasions when it took the practical form of a refusal to allow us board and lodging until assurance was given that we were what we represented ourselves to be. Once we were interviewed by a gentleman from the Intelligence Department at Halifax, to whom it was only necessary to show a letter from Col. Lang of the Headquarters Staff of Military District No. 6, endorsing this work, with which the writer had taken the precaution to provide himself when in Halifax.

Having completed the Halifax section the party then proceeded to extend the reconnaissance eastward from Truro. On July 29 the party visited Camden and Nutby, and then went on to Dalhousie and Eastville. From Dalhousie mountain the view towards Camden was cut off by a ridge about a mile and a quarter to the south, so the station was placed there, as it commands a view of

all the surrounding stations, although Dalhousie Mountain is a trifle higher. At Eastville probably the same point as that selected for a station by Mr. Moulton was found. From it Barr may be observed.

New stations were also established at Blue Mountain and Arisaig, the latter being near a village by that name on the shore of Northumberland sound. From it may be observed Dalhousie, Picton Island, the two stations on Prince Edward Island, and those on Cape Breton, and possibly Blue Mountain, though the last is not essential.

Whenever an opportunity occurred an observation was taken to determine the magnetic declination. The value of that quantity was thus determined at eight different points, a report of which has already been made.

Old rock cairn covered with lichens used by Militia surveys—Station "Taggart," near Halifax.

Progress in Observing horizontal angles at the Head of the Bay of Fundy.

C. H. Brabazon, Geodetic Engineer, submits the following report of his work during the season of 1918.

During the field season of 1918 the writer was in charge of a triangulation party in the vicinity of the head of the bay of Fundy, observing the horizontal angles of the primary triangulation.

The operations started near the end of May, about 40 miles east of St. John, N.B., and continued east around the head of the bay of Fundy, till September 26, when, the appropriation for the work being spent, operations were suspended for the season.

It was somewhat unfortunate that these considerations held up the progress of the party, as the fall weather is undoubtedly the most propitious for triangulation near the bay of Fundy, the summer fogs being seldom seen at that season, so that, in general, the progress is better from August on, than earlier in the season. Another rather unfortunate feature was that the occupation of three

more stations would have completed all the observations necessary in the bay of Fundy net, and would have permitted the final adjustment of that section of triangulation.

A big obstacle to rapid progress of a triangulation party in the bay of Fundy region and in Nova Scotia is the fog which rises from the water about sundown, just when the observing starts for the night. Thus in the months of June and July there are many days on which observations might be expected but on which night observing is impossible. This may be illustrated by the fact that during the season of 1918 from May 25 to August 1 only two stations were occupied, while from August 1 to September 25 the observations at six stations were made.

Another hindrance to rapid progress last season was the difficulty and expense of transport from station to station. Teams were scarce and expensive, entailing the waste of precious time in moving camp. In this work the successful utilization of the spells of clear weather is the important consideration. These periods generally last about three to five days, and the observer generally finishes his work at a station a day or two after a clear period commences. If he now uses two or three days of this clear weather moving his outfit from station to station he is liable to reach the next station only to find that this period of clear weather has passed and he must stay inactive until the next.

It is hoped that this condition of affairs will be remedied during the season of 1919 by making a one-ton motor truck part of the regular equipment of triangulation parties, when it is confidently expected that the faster progress of the party will mean a saving of a considerable amount in a single season.

Operations in Tower Building

In the absence of N. E. Kelly, the following report of the operations of the tower building party under his charge during the summer of 1918 in New Brunswick and Nova Scotia was prepared by J. L. Rannie.

The work of the party consisted in building observing towers or instrument stands for the primary triangulation observers; the marking and referencing of stations, either by copper bolts leaded into the rock or by small concrete monuments; together with the building of signals, etc., for secondary triangulation.

The party started work on the north shore of the bay of Fundy near Alma, N.B., about May 15, and continued its operations around the head of the bay of Fundy and thence eastward towards Halifax, completing its work on the 13th of November.

The personnel comprised the chief of the party, four assistants, and a cook until July 12, when one of the assistants had to leave. He was not replaced and the party continued one man short till the end of October, when the main work of the party was completed. From then till November 13 Mr. Kelly and one man were engaged in completing some small jobs which had not required the time of the whole party.

Hereunder is a statement of fifteen towers erected:—

1 with 70-foot tripod, 76-foot scaffold.
2 with 50-foot tripod, 56-foot scaffold.
3 with 45-foot tripod, 51-foot scaffold.
7 with 35-foot tripod, 41-foot scaffold.
1 with 25-foot tripod, 31-foot scaffold.
1 with 20-foot tripod, 26-foot scaffold.

These towers were built according to standard plans of this Survey. The timber was in all cases obtained locally, either round timber, which was cut in the woods nearby, or sawn timber from local mills being used.

Where the triangulation station lies on bare rock, it is marked by a $\frac{3}{4}$-inch copper bolt leaded into the rock, surrounded by an equilateral triangle with 8-inch sides cut in the rock. In general, it is referenced by three similar bolts with arrows cut in the rock pointing to the station. Where the rock has a thin covering of soil with underbrush or bush, the station is marked by the copper bolt mentioned above, which is surmounted by a cube of concrete one foot square around three reinforcing iron bolts, the ends of which are leaded into the rock. Another copper bolt is placed in the top of this monument.

Where the station occurs in the bush where there is no rock near the surface and where there is no convenient place to build a reference monument as mentioned below, a concrete monument is set to mark the station itself. This consists of a concrete cube with sides three feet long, surmounted by a concrete block with sides one foot long, the two blocks being held together by reinforcing iron rods. The top of the larger block is about six inches above the surface of the ground. A copper bolt in the upper block marks the centre of the station.

Where the station occurs in cultivated country, or where a reference monument may be conveniently placed, the station is marked by an underground and a surface mark, consisting of 4-inch drain tile filled with and surrounded by concrete and rocks. The tops of the underground and surface marks are about four feet and one foot respectively below the surface. In such cases a reference monument, placed in a convenient fence corner, is built similar to the station monument mentioned in the preceding paragraph.

It may be said that 17 monuments were placed as mentioned above and three stations marked only by copper bolts in the rock.

Seven signals for secondary triangulation were erected in the Moncton, N.B., region. These consist, in general, of a tripod surmounted by a pole carrying diamond-shaped cotton signals. They are so built that the observer's instrument may be placed over the station without touching the overhead signal.

In view of the delays which occurred last season due to a scarcity of teams, together with the high prices for transport which had to be paid, it is strongly recommended that this party be provided with a Ford truck next season. A large proportion of the cost should be saved in one season.

Precise Levelling in 1918

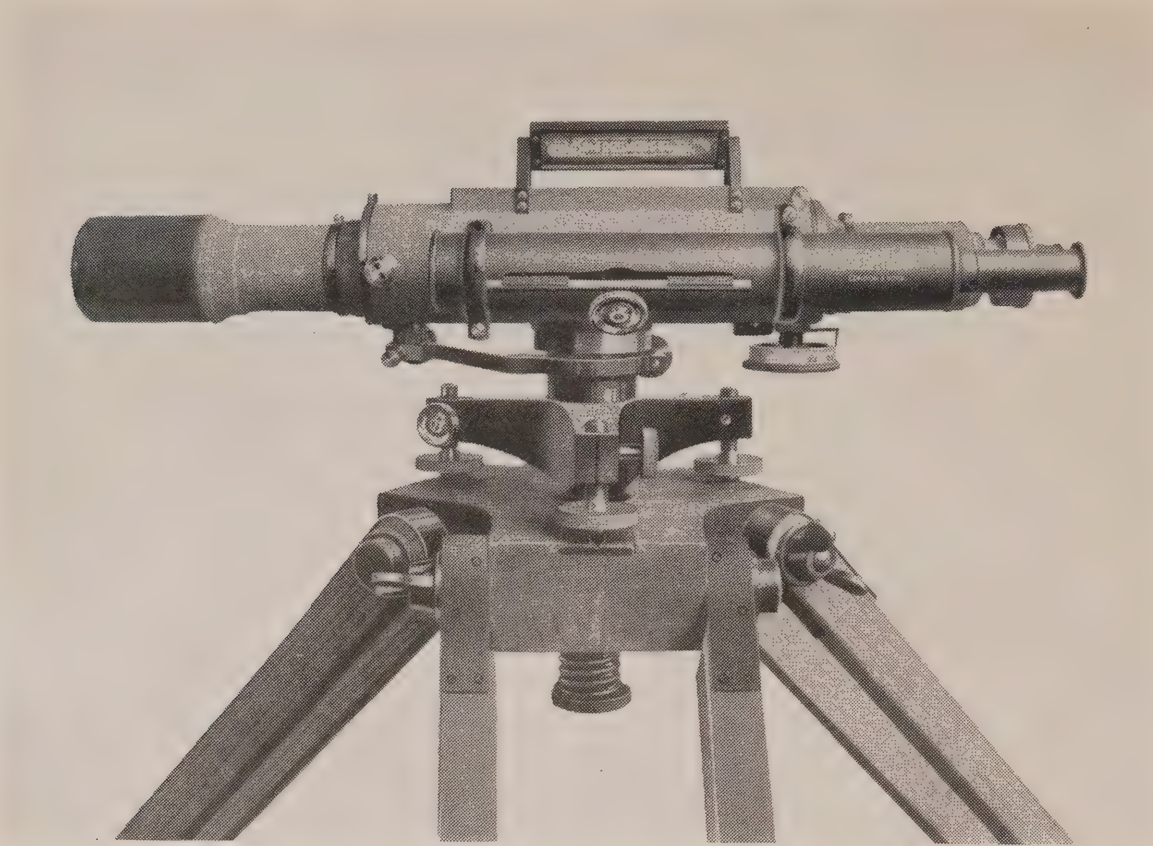
F. B. Reid, Supervisor of Levelling, submits the following progress report upon precise levelling operations during the season of 1918.

Three parties were in the field: two in western Canada, in charge of Messrs. McMillan and Rainboth, and one in the East, in charge of the writer.

Levelling by D. McMillan.—This party left Ottawa on April 27 for Rosser, Man., and commenced levelling on May 2, continuing the line from Winnipeg which had been started the previous season and discontinued in the fall near Rosser. The Canadian Pacific railway was followed to Portage-la-Prairie and the Canadian Northern railway from there to Neepawa, at which point the line closed on the Napinka-Neepawa line run by Mr. McMillan in the early part of 1917.

Levelling at Neepawa being completed on July 10, the party moved to Yorkton, Sask., and spent the balance of the season till October 2, on a line following the C.P.R. from that point to Saskatoon. By the latter date the levelling had reached the village of Colonsay, 38 miles east of Saskatoon; weather conditions would doubtless have allowed the completion of the line, but, owing to a shortage of funds, it was found necessary to recall the party and allow the balance of the levelling to stand over till next season.

Levelling by A. J. Rainboth.—This party left Ottawa on April 27 for Minnedosa, Man., and spent the full season (May 2 to October 8) on a line from there



Precise Level of the Geodetic Survey of Canada—United States Coast and Geodetic Survey Pattern.

to Regina, Sask., following the Winnipeg-Edmonton line of the Canadian Pacific railway as far as Yorkton, and the Grand Trunk Pacific railway from Yorkton to Regina. At Regina the line was closed on the original line of precise levels run through southern Manitoba and Saskatchewan in 1910–11–12.

A reference to the map at the back of this report will show that this year's levelling in the West has closed two more circuits composed entirely of our own levelling. The circuit Napinka-Minnedosa-Winnipeg-Sprague-Emerson-Napinka has a closure of 0.038 foot with a perimeter of 605 miles, while the circuit Regina-Yorkton-Minnedosa-Napinka-Estevan-Regina has a closure of 0.023 foot with a perimeter of 652 miles. These remarkably small closings are particularly gratifying in view of the adverse weather conditions usually encountered on the prairies.

Messrs. McMillan and Rainboth utilized railway motor cars in place of hand cars throughout the season's work.

Levelling by F. B. Reid.—This party left Ottawa on May 7 and commenced levelling the next day at Papineauville, Que., the work first undertaken being the completion of the line to Hull, which had been extended as far west as Papineauville the previous season. A little less than three weeks sufficed for this section, and the following two months were spent on the extension of levels from Grenville, Que., to Prescott, Ont. A somewhat irregular and interesting route was traversed by this line; starting from a bench-mark near Grenville station, which is almost exactly the central point of the Montreal-Hull line of levels, country roads were followed to the shore of the Ottawa river and the C.N.R. bridge was used to cross to Hawkesbury. Here a bench-mark of the Public Works Department (Georgian Bay Ship Canal Survey) was tied in and levelling was continued along the G.T.R. through Glen Robertson to St. Poly-

carpe Junction, at which point two bench-marks of our original Rouse Point–Toronto line (1908) were incorporated with the new line. The recently completed Cornwall branch of the C.P.R. was followed to the town of Cornwall and a connection made with the Finch–Cornwall line of levels, run in 1913 as a spur line from Finch, also with the Public Works Department's levels from Montreal to Cornwall.

The route for the balance of the distance lay along the main line of the G.T.R. from Cornwall to Prescott, parallelling the shore of the St. Lawrence river. At Prescott the line was terminated on two more bench-marks of the Rouse Point–Toronto line.

The next levelling was along the C.P.R. Smith Falls–Toronto line from a point near Indian River to North Toronto station. The levels had been carried to the neighbourhood of Indian River by W. N. McGrath in 1916, and the present levelling was an extension of his operations. During the progress of the line two branches were run to form connections with the original line of levels lying along the lake front (G.T.R. main line). One of these branches ran to Port Hope from a point near Bethany, the other was from Myrtle to Whitby; both were run over Grand Trunk tracks. After closing on one of our old bench-marks at North Toronto station the line was extended along the C.P.R. tracks through West Toronto and Islington and down to the G.T.R. Toronto-Hamilton line at a point near the village of Mimico, connecting here with with another of the old bench-marks. Thus there is formed a loop line of precise levels around the outskirts of the city of Toronto, with permanent bench-marks at short intervals.

The net result of the season's operations by this party was the formation of eight additional circuits of levelling between Montreal and Toronto. Field work was completed and the party disbanded on October 1.

A noteworthy feature of the season's work in Quebec and Ontario is the unusually large number of bench-marks established and the fact that a majority of them ought to prove of exceptional permanence and stability. Fourteen standard bench-mark piers were built and in addition ten branch lines were run for the purpose of setting bench-marks in stone Roman Catholic churches. Churches were utilized at the following places: Thurso, Ste. Rose-de-Lima, Pointe Gatineau, Grenville, Hawkesbury, Glen Robertson, St. Polycarpe, St. Telesphore, Prescott and Peterborough.

Camps were established at twenty towns and villages in the course of the season's levelling, the average distance worked from each camp being about 15 miles. Experience shows that with a hand car (not a motor car) for purposes of transport to and from work this length of move is about the most economical one; with more frequent moves too much time is lost in taking down and setting up camp, while with moves of much more than this distance the time spent each day in going to and from work tends to become excessive and more than counterbalances any saving at camp. With a motor car the range of levelling from a camp can be considerably extended and moves of 20 or 25 miles or more made without sacrifice of time.

SUMMARY OF FIELD WORK

The mileage levelled (run in both directions) is shown in the following table, also the percentage of levelling by each leveller, the number of standard bench-mark piers built and the total number of bench-marks established, including piers.

Leveller.	Mileage Levelled.	Mileage Re-levelled.	Piers Built.	Total B.-Marks Established.
D. McMillan	269	7%	16	62
A. J. Rainboth	267	10%	15	83
F. B. Reid	295*	10%	14	126
Total	831	....	45	271

*In addition to the 295 miles of new levelling it was found necessary to re-run three sections of previous year's work, aggregating 12½ miles.

Summary of Lines Levelled in 1918.

Line.	On Railway.	Branches.	Total.
From 11·8 miles west of Winnipeg to Neepawa, Man	104·8	1·0	105·8
Yorkton to Colonsay, Sask	163·4	0·1	163·5
Minnedosa, Man., to Regina, Sask	266·1	0·8	266·9
Papineauville to Hull, Que	38·4	2·6	41·0
Grenville, Que., to Prescott, Ont	103·0	14·0	117·0
From 8 miles east of Peterborough to North Toronto	81·5	2·7	84·2
Bethany to Port Hope, Ont	22·3	1·2	23·5
Myrtle to Whitby, Ont	13·1	1·6	14·7
North Toronto to Mimico, Ont	14·0	0·4	14·4
	806·6	24·4	831·0

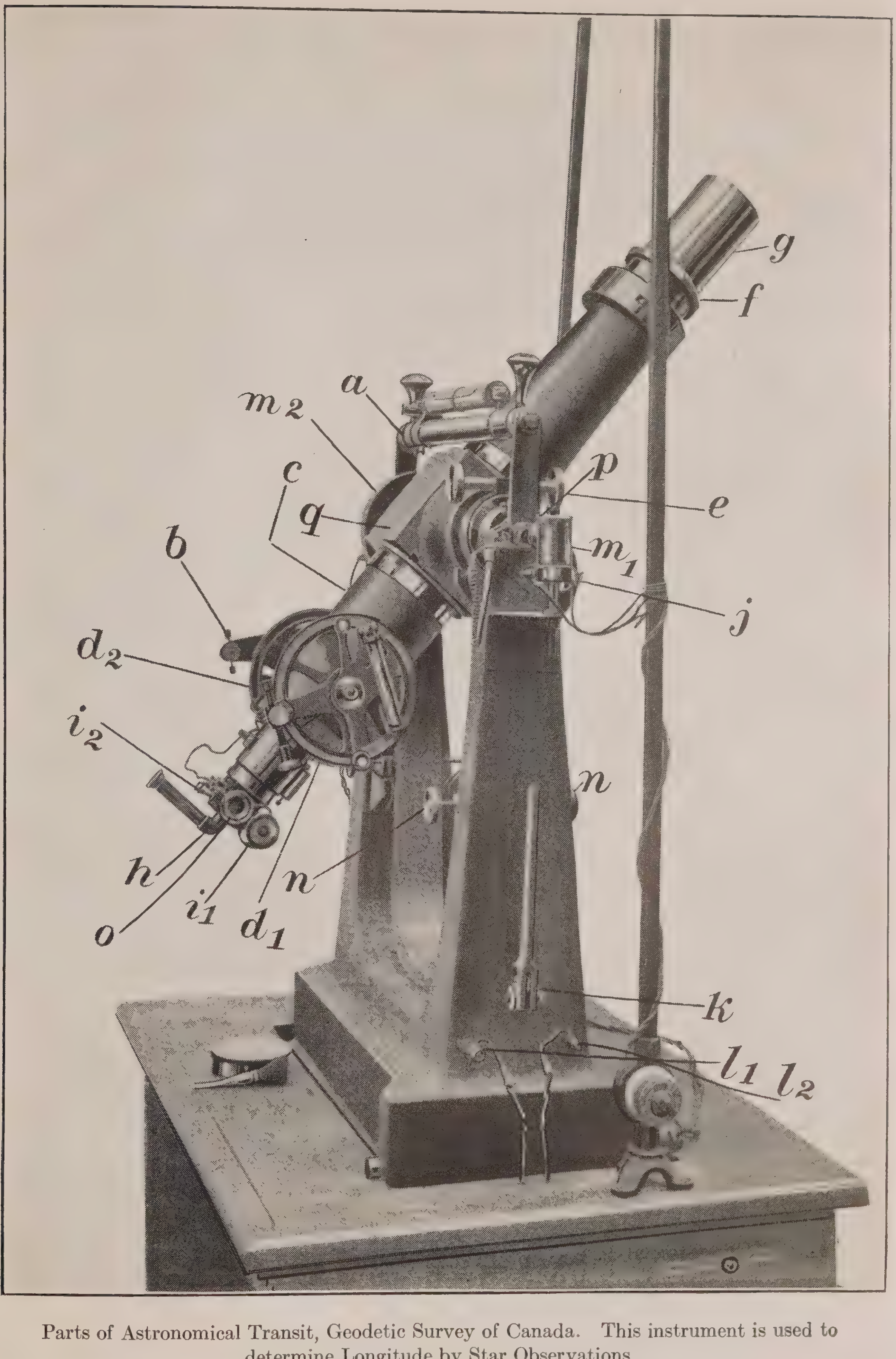
Field Astronomy and Standardization of Base Line Tapes

F. A. McDiarmid, Supervisor of Standards, reports as follows on Field Astronomy and Standardization of Base Line Tapes during the year.

Introduction.—In this report the progress of field operations in determining longitude, azimuth and latitude and the determination of the length of the three fifty-metre invar base line tapes will be described. But before doing so it is well that some mention should be made of the instruments employed and the methods followed in the astronomical work of the Geodetic Survey of Canada. The methods used in this Survey are those in vogue in the leading Geodetic Surveys of the world, and for future reference, it is felt that a description of the instruments, and of the methods should be in the records of the Survey.

Among the more important items to be considered in this report are: Description of transit instrument with micrometer attached; chronograph and chronograph circuits, determination of time and longitude using the transit micrometer, descriptions of the micrometric-direction method of azimuth observation and of the zenith distance method of latitude determination, astronomical observations made at Klucksiwi, B.C. Astronomical observations made at Halls Hill, N.B., tables of results of longitude observations made in 1917 and 1918, and standardizing of the three invar field tapes from Standard Nickel bar No. 10239.

Astronomical Transit.—The astronomical transit of the Geodetic Survey of Canada, Cooke No. 2, is shown on page 67. It has a focal length of about thirty inches and a clear aperture of two and one-half inches, is provided with a convenient reversing apparatus shown as k_1 by means of which it can be reversed in the wyes, m_1 and m_2, without touching the telescope by hand. The striding level, a_1 is used for measuring the difference of elevations of the pivots, one division of the level is equal to 1·08 seconds. The setting circles, e_1 and e_2 are about four inches in diameter, and are graduated to read to minutes by means of a vernier. To one of the setting circles, d_2, is fixed a fine level, l, for the purpose



Parts of Astronomical Transit, Geodetic Survey of Canada. This instrument is used to determine Longitude by Star Observations.

of latitude observations. To the level is attached a mirror, *c*, to read accurately the position of the level bubble; a dew cap, *g*, is shown fitted over the object glass, *f*. The telescope is held in position by means of a clamp, *e;* and through the tangent screw, *n*, the telescope may be moved slowly in zenith distance. To the eye end of the telescope is fitted a transit micrometer. The transit micrometer is a form of registering micrometer placed with its movable wire in the focal place of an astronomic transit and at right angles to the direction of motion of the image of the star which is being observed near meridian transit. Certain contact points on the micrometer head, *o*, serve, to make an electric circuit as they pass a fixed contact spring, thus causing to be recorded upon the chronograph sheet each separate instant at which the micrometer wire reaches a position corresponding to a contact. The micrometer is driven by hand, two wheels i_1 and i_2 being provided for the purpose. Inside the micrometer there are four combs, the width of each is five turns of the micrometer, and the space between any two consecutive combs is also five turns of the micrometer. These combs are so placed in the micrometer box that they are symmetrical with respect to the field, the outside breaks of the outside combs being seventeen and one-half turns from the centre of the field. Cut-out's on one of the wheels of the micrometer mechanism correspond to the combs inside the box. A rectangular diagonal eye-piece, *h*, is used so that the observer is sitting in a comfortable position when taking observations. The field of the telescope is illuminated by two small electric lights *m* and *m*, which are placed in front of an aperture, *p*, in the axis of the telescope. The light is reflected from a mirror attached to the block, *g*, to the eye end of the telescope, illuminating the micrometer wires. To the binding posts, l_1 and l_2, are attached wires which lead to the switch board and batteries. These posts are connected through the instrument to the micrometer eye-piece, and provide the means through which the observations are registered. The currents for the different circuits are supplied by dry cells. The micrometer eye-piece is so fixed to the telescope tube that it can be readily turned through a right angle. Then the micrometer wire will, instead of being in or parallel to the meridian, cut the meridian at right angles and the transit is converted into a zenith telescope for measuring the differences of zenith distances of two stars of nearly equal zenith distances on opposite sides of the zenith.

Chronograph.—The form of chronograph now in use in the Survey field work is shown on page 54 of the 1918 report. The clockwork is driven by a falling weight. It drives the speed governor (seen above the case containing the gears) the cylinder upon which the record sheet is wound, and the screw which gives the pen carriage a slow motion parallel to the axis of the record cylinder. When the speed governor is first released, the speed continually increases until the governor balls have moved far enough away from the axis of revolution to cause a small projection upon one of them to strike a small hook. This impact and the effect of the friction at the base of the weight attached to the hook, causes the speed to decrease continually, until the hook is released. The speed again increases until the hook is engaged, decreases until released, and so on. The total range of variation is, however, very small, so small that in interpreting the record of the chronograph the speed is asumed to be uniform during the interval between chronometer breaks. The speed may be regulated by moving the governor balls, or by moving the projection attached to one of the balls. To get a convenient record the speed of the governor is so adjusted that the drum carrying the chronograph sheet revolves once every minute. The chronograph circuit, passing through the coils of the pen magnet, is led over the points of a relay operated by a circuit connected to the chronometer. This insures a sharp lateral movement of the recording pen, attached to the pen armature on the breaking of the circuit, and a corresponding sharp offset or break is secured in the helix which the pen traces on the paper on the drum. When making star observations, the transit circuit passing through the transit, the

micrometer head and the coil of the transit relay, is connected with the chronograph circuit through the points of the transit relay. The chronometer circuit passes through the coil of a relay over the points of which it is connected with the chronograph circuit.

In operation the chronometer breaks the circuit automatically every two seconds and the pen records the breaks upon the moving sheet at equal linear intervals. The chronometer is so arranged to indicate the beginning of each minute by either omitting the break at the fifty-eighth second or by putting in one at the fifty-ninth second. The hours and minutes may be identified by writing upon some point of the sheet, the corresponding reading of the face of the chronometer.

The record of the exact time of the transit of a star is obtained in the following manner: The image of the star is bisected when it comes near the part of the field where it is desired to observe. A cut-in is arranged on one of the wheels of the micrometer that permits the making of the circuit when the strips in the wheel are opposite the contact spring.

It is also arranged that a star is observed sufficient time before it crosses the meridian to permit of the reversal of the telescope in its wyes and the star again observed over the same part of the field, as the star recedes from the field. As the wire passes the various positions corresponding to contacts on the micrometer head the transit circuit is automatically made and through the action of the relay it automatically breaks the chronograph circuit and produces a record on the chronograph sheet. The fractions of a second from the chronograph sheet are read by means of a scaling glass.

Adjustment of Transit Instrument.—The concrete pier on which the instrument is to be mounted is built rectangular to the meridian. The dimensions of the pier are 27 inches by 20 inches and the top of the pier is 30 inches above the floor of the observatory. The depth of the pier in the ground depends on the nature of the soil; the bottom of a pier on ordinary clay or sandy soil should be about four feet below the surface. The pier stands with its 27-inch side perpendicular to the meridian. It is so placed by means of a compass. In preparing an instrument for observing there are three adjustments necessary, level, collimation and azimuth. The transit is placed on the pier with its axis approximately parallel to the line cutting the meridian at right angles. The horizontal axis is levelled by the striding level. Care must be taken to see that the level bubble is in adjustment. After almost every shipment of the outfit it is necessary to adjust the level itself.

It is also necessary to test the verticality of the micrometer wire. This may be secured by pointing upon some well defined object, and rotating the transit slowly about the horizontal axis and making the wire follow it throughout its length. To adjust the collimation, place the micrometer wire in its mean position, as indicated by the combs, in the middle of the field. If possible set on some well defined object, keeping the wire in its central position, reverse the telescope in its wyes and again observe the object. If the wire still bisects the object, the instrument has no error of collimation. If upon reversal the wire does not again bisect the object, the adjustment is made by bringing the wire half way back to the object with a screw on the eye-piece provided for the purpose. Often it is necessary to make this adjustment at night. An experienced observer is able to make use of a slow moving star for the purpose. He first sets on a polar star and reads the micrometer, reverses the instrument and again sets on the star reading the micrometer—reverses again and sets on the star and again reads the micrometer. If he has been uniform in his operations the distance of the second reading from the centre of the field should be equal to the mean of the other two. One who has had experience will, after a couple of trials, reduce the error of collimation to a small quantity. The azimuth

adjustment is brought about as follows: The setting circles are first adjusted to read declinations, and the chronometer is set at approximate sideral time. This may be done by applying the approximate difference of longitude as scaled from a map to the sideral time at some known place, or by reducing from the standard time the sideral time at the station whose longitude is approximately known. This will give the sideral time within two or three minutes. Some star is then selected which will transit near the zenith. Observe the chronometer time of transit of this star. The time of transit of a zenith star is but little affected by the azimuth of the instrument. The collimation and level having been made small by adjustment, the right ascension of the star minus its chronometer time by transit will be a close approximation to the chronometer correction. Now set the telescope for some star of large declination which is about to transit to the northward of the zenith. Compute its chronometer time of transit, using the chronometer correction found from the zenith star. As that time approaches, bisect the star with the micrometer wire in its mean position in the centre of the field, and keep it bisected, following the motion of the star in azimuth by the slow motion screws provided for that purpose, until the chronometer indicates that the star is on the meridian. The adjustment is generally tested by repeating the process. This adjustment in azimuth can be often carried out on polaris in daylight and by using some star of first or second magnitude for time determination.

Determination of Time.—Previous to starting on a longitude campaign or before commencing a series of time observations, a suitable programme of stars is selected. The time stars best adapted for time observations are within twenty degrees of the zenith, and the north stars are in declination about 80°. A time set consists usually of twelve to fifteen stars, eight to eleven south of the zenith, but north of 15° declination, and three to five polars between 73° and 82° declination. Such a set will give a chronometer correction with a very small amount of error. In taking time observations the following procedure is followed. The axis of the telescope is first carefully levelled, and when time has been given for the instrument to settle after levelling, the level is read with the object glass north and south and in clamp east and west, making four readings in all. The stars of the observing programme should be so selected that level readings may be made at intervals during the progress of the night's work. If the pier is steady, and there is small change in the level, fewer level readings are necessary, but if the pier shows change then the level must be read frequently.

Personal Equation.—When the results of time observations made by two observers at the same meridian, or when results are reduced to the same meridian, they are generally found to differ by small amounts.

Previous to the introduction of the transit micrometer these amounts were of considerable dimensions often reading one-half a second. This difference is called personal equation, and must be applied to two observations used for longitude determination. Of course it is only the relative personal equation which is determined.

While the transit micrometer has greatly reduced the size of the personal equation, yet it still exists, and is not altogether constant. The process followed in the Geodetic Survey's longitude work is to observe for personal equation just before the field campaign commences and again immediately at the close of the season; when a considerable interval of time intervenes between stations, if at all practical, personal equation observations should be made during the season as well as at the beginning and end.

During the season of 1918, as the observations at Hall's Hill followed almost immediately those at Klucksiwi, personal equation observations were made only in May and June before the Klucksiwi observations, and at the end

of August after finishing Hall's Hill. The base for the longitude determination of both Klucksiwi and Hall's Hill was Ottawa. The personal equation determinations were all made at Ottawa. Below follows the table of the determinations of personal equation:—

Epoch.	Personal Equation.
	s
May, 1917	— ·066
July, 1917	— ·098
September, 1917	— ·150
June, 1918	— ·099
August, 1918	— ·142

This table shows the absolute necessity of frequent determinations of personal equation if the longitude is to be determined with a great degree of accuracy.

Difference of Longitude.—The meridian at Greenwich is the base of all our longitude, and the determination of a new station is only determining the difference of time between it and Greenwich, or between it and some station whose longitude is known. The determination of a difference of astronomic longitude is merely a determination of the difference of local times at the two stations.

The determination of longitude between two stations, consists of two sets of twelve to fifteen stars at each station with an exchange of clocks signals between them. The two observatories are connected by means of a telegraph line. A wire has to be run from the switchboard in the observatories to the nearest telegraph line.

Longitude—Klucksiwi, B.C.—The astronomical station at Klucksiwi is on a hill on the northern part of Vancouver island, about seven or eight miles from Alert bay, and overlooking Queen Charlotte sound. Klucksiwi is one of the stations of the primary triangulation. The point selected is on the highest point of the hill at an altitude of about fourteen hundred feet above sea level. It is about two and a half miles by trail from the beach at Pt. McNeil. For about one-half this distance, or to the crossing of the Klucksiwi river there was an old trail put in about ten years ago by a mining company. This trail is still in good condition, and little difficulty was experienced in transporting the instruments and supplies to the Klucksiwi river. From Klucksiwi river to the top of Klucksiwi mountain, a rough trail was made, but as the grade was very steep, a good deal of difficulty was experienced before the outfit was safely at the top. Happily, it was not necessary to pack cement for the pier; a large tree with the top cut off, had been selected for the Geodetic point, and after examination it was decided to use this stump for mounting the astronomical transit. A platform was built around but entirely away from the stump, and one of the observing tents was mounted over it. The observations and especially the level readings show that the stump made a splendid base for the astronomical transit, the level readings for any one night being nearly identical. There were considerable changes from night to night, due perhaps to the action of the sun on the ground surrounding the stump.

The difference of longitude between Klucksiwi and Ottawa was determined from observations on July 8, 11, 12, 14 and 15. On each of these nights, except July 8, the full quota of stars was obtained, a full set of twelve to fifteen stars both before and after exchange. On the 8th of July one set only was observed, the second set being cut off by a dense fog from Queen Charlotte sound.

For the purpose of the signal exchange the Canadian Pacific railway telegraph line from Ottawa to Vancouver, C.P.R. cable Vancouver to Nanaimo, and the government telegraph line from Nanaimo to Klucksiwi via Campbell River. The total mileage was about 3,300. The C.P.R. connections from Ottawa via Montreal to Vancouver, and on to Nanaimo were perfect as is possible to obtain over such a long wire. The government line from Nanaimo to Klucksiwi runs through a rough country, that section of the line north of Campbell River being a tree line, and the underbush has grown up to such an extent that there was more or less escape, especially when the weather was wet. The first night of the exchanges an attempt was made to work through direct from Klucksiwi to Vancouver without repeaters. After a good deal of difficulty a satisfactory connection was secured between Ottawa and Klucksiwi and the exchange of signals was effected. On the following nights, on the suggestion of the writer, a half set of repeaters was installed at Campbell River and the exchanges were afterwards effected without difficulty. A word of appreciation for Mr. J. T. Phelan, the Government Telegraph Superintendent at Vancouver, and Mr. Slocombe, the Government operator at Campbell River, is here cheerfully given. Both of these gentlemen gave their assistance and without their efforts the work would not have progressed so favourably. The first exchange was on the evening of July 8. On account of rain and fog, no attempt was made to use the telegraph line on the 9th or 10th, but perfect conditions prevailed on the 11th, 12th, 13th, 14th, and 15th, and the work was completed.

Longitude at Hall's Hill.—Hall's Hill is a rocky hill on the Sackville–Pt. Elgin road about thirteen miles from Sackville, N.B. The triangulation station at Hall's Hill is at the east end of the Westmorland base. The point is marked by a copper bolt in the rock. A concrete pier was built over the point; an inch and a half iron pipe was placed over the bolt and in the centre of the pier. This pipe came nearly to the top of the pier. In this way the bolt was protected from the concrete and the instrument was easily centred over the bolt. The dimensions of the concrete pier were 20 by 27 inches and 34 inches high. A wooden shack was built over the pier to protect the instruments from the weather and for convenience in observing. The telegraph connection for the exchange of time signals with Ottawa was furnished by the Great North Western and Western Union Telegraph Companies, the G.N.W. Ottawa to St. John, and the Western Union from St. John to Sackville. From Sackville to Hall's Hill the wires of the New Brunswick Telegraph Company were used. A wire was run from the telegraph office at Sackville to the Western Union telegraph office and attached to the telegraph switchboard. In the telephone office there was installed a set of coils by which the two wires of the metallic telephone circuit, Sackville to Pt. Elgin, were lead to a neutral point. To this neutral point was attached the telegraph wire. At Hall's Hill observatory a second set of coils was installed, and a wire lead from the neutral point of this set to the longitude switchboard and a wire leading from the switchboard to the ground complete the circuit. A telephone was installed in the observatory to enable the observer to call the telegraph office and make arrangements for the exchanges. This arrangement gave perfect satisfaction and was decidedly cheaper than building a telegraph line.

Observations for longitude commenced on August 8, and were finished the night of the 20th. The sky was clear on the nights of August 8, 9, 10, 12, 15, 16, 17, 18, 19, 20, but, owing to the action of a bolt of lightning burning the electrical connections of the chronometer and making it necessary to secure a new one from the office, the nights of the 15th and 16th were lost for longitude. On the night of the 12th the telegraph wires between Montreal and St. John, N.B., were broken, and no exchange was possible. Seven determinations of longitude in all were secured.

Latitude.—In the latitude determinations of the Geodetic Survey of Canada Talcott's zenith distance method of latitude determination is used. The difference of zenith distance of two stars of nearly equal zenith distance on opposite sides of the zenith is measured by means of the micrometer and level. A full description of the method is given in Hayford's Geodetic Astronomy, page 164.

At Klucksiwi, B.C., twenty-three pairs of stars were observed and at Hall's Hill fifty-five pairs.

Azimuth.—The process of determining the azimuth or direction of a terrestrial line astronomically consists of a measurement of the angle between two vertical places—one defined by the azimuth mark, and the other by the observed star and the vertical at the instrument. Since the angle between these two places is continually changing the exact time at which each pointing is made upon the star must be noted upon a chronometer of which the error may be determined. For this recorded time the hour angle of the star and its azimuth as seen from the station may be computed. The computed azimuth of the star combined with the measured horizontal angle between the vertical planes of star and mark will give the azimuth of the mark from the observing station. At Laplace stations (coincident triangulation, longitude, and azimuth stations) the astronomic azimuth should have a probable error not greater than 0.25″, and the observations should be made on two or more nights. One of the ground stations of the main triangulation is always chosen for a Laplace determination.

The azimuth observations are always made at night, and the azimuth mark is indicated by one of the carbide lamps of the Survey. The size of the light depends upon the distance from the observing station. A light of three inches diameter shows at a distance of twenty-five miles about the brightness of a third magnitude star.

A complete set of azimuth observations at a station consists of sixteen sets, in sixteen different positions of the horizontal plate. Sixteen sets under fair observation conditions will give a result with probable error less than 0.20″.

At Klucksiwi, B.C., the azimuth of the line Klucksiwi to Harbledown was observed, and at Hall's Hill, N.B., the line Hall's Hill to Pont-à-Buot.

In order to get the chronometer correction time the stars in the vertical of polaris are observed. This method of time determination is simple, and gives a result accurate within a half-second.

Astronomical Observations at Collingwood, Southwold, and Pouce-Coupé.—The stations at Collingwood, Southwold, and Pouce-Coupé were occupied during the season of 1917, but the final checked computations were not completed in time for last year's report. Collingwood and Southwold are two stations of the primary triangulation in Western Ontario. The astronomical longitude and azimuth combined with the geodetic longitude and azimuth constitutes what is known as the *Laplace equation*, which gives the *twist* or *turning* of the triangulation.

Pouce–Coupé is near the British Columbia–Alberta boundary line. The one hundred and twentieth meridian of longitude is the boundary line between the province of British Columbia and Alberta to the north of where said meridian meets the summit of the Rocky Mountain range. The position of the 120th meridian was deduced from the results of the longitude determination at Pouce-Coupé.

Laplace Station at Hall's Hill, N.B. A Laplace Station is a Triangulation Station at which Astronomical Observations for Longitude and Azimuth are made.

DIFFERENCE of Longitude between Ottawa, Ont., and Collingwood, Ont.

Date	Difference of Chronograph		Clock Correction		Difference of Longitude			Time of Transmission
	Western Signals	Eastern Signals	Western Station	Eastern Station	Western Signals	Eastern Signals	Mean	
1917.	m s	m s	m s	s	n s	m s	m s	s
June 14....	−17 20·302	−17 20·189	− 1 20·164	−14·501	−18 25·965	−18 25·852	−18 25·908	·057
" 16....	−17 26·997	−17 26·888	− 1 15·697	−16·686	−18 26·008	−18 25·899	−18 25·953	·055
" 20....	−17 30·483	−17 30·375	− 1 18·540	−23·019	−18 26·004	−18 25·895	−18 25·949	·054
" 21....	−17 30·412	−17 30·298	− 1 18·702	−23·099	−18 25·015	−18 25·901	−18 25·958	·057
" 22....	−17 30·066	−17 29·926	− 1 19·200	−23·249	−18 26·019	−18 25·879	−18 25·949	·060
" 24....	−17 35·989	−17 35·886	− 1 19·449	−23·477	−18 25·961	−18 25·858	−18 25·910	·052
							h m s	
					Mean........................		0 18 25·938	
					Personal equation............		0 0 0·080	
					Difference of longitude.......		0 18 26·018	
					Longitude of Ottawa.........		5 02 51·983	
					Longitude of Collingwood....		5 21 18·001	
					Correction of Geodetic point.		0 0 0·015	
					Longitude of Geodetic point.		5 21 17·986	

DIFFERENCE of Longitude between Ottawa, Ont., and Southwold, Ont.

Date	Difference of Chronograph		Clock Correction		Difference of Longitude			Time of Transmission
	Western Signals	Eastern Signals	Western Station	Eastern Station	Western Signals	Eastern Signals	Mean	
1917	m s	m s	s	s	m s	m s	m s	s
June 29....	23 00·462	23 00·250	−18·417	−30·094	22 48·785	22 48·573	22 48·679	·106
" 30....	22 59·581	22 59·437	−19·365	−30·230	22 48·716	22 48·572	22 48·644	·072
July 1....	22 58·445	22 58·288	−20·645	−30·354	22 48·736	22 48·579	22 48·657	·079
" 2....	22 57·478	22 57·327	−21·765	−30·492	22 48·751	22 48·602	22 48·676	·074
" 4....	22 02·947	22 02·727	−22·632	+23·236	22 48·815	22 48·595	22 48·705	·110
							h m s	
					Mean........................		0 22 48·672	
					Personal equation............		0 00·089	
					Difference of longitude.......		0 22 48·761	
					Longitude of Ottawa.........		5 02 51·983	
					Longitude of Southwold......		5 25 40·744	
					Correction to Geodetic point.		+·011	
					Longitude of Southwold Geodetic point................		5 25 40·755	

DIFFERENCE of Longitude between Ottawa, Ont., and Pouce-Coupé, B.C.

Date	Difference of Chronograph		Clock Correction		Difference of Longitude			Time of Transmission
	Western Signals	Eastern Signals	Western Station	Eastern Station	Western Signals	Eastern Signals	Mean	
1917	h m s	h m s	s	s	h m s	h m s	h m s	s
July 25...	2 57 22·775	2 57 22·296	− 1·387	+15·887	2 57 40·049	2 57 39·570	2 57 39·810	·239
" 26...	2 57 22·087	2 57 21·613	− 2·260	+15·709	2 57 40·056	2 57 39·582	2 57 39·819	·237
Aug. 12...	2 57 25·882	2 57 25·446	−15·905	− 1·798	2 57 39·989	2 57 39·553	2 57 39·771	·218
" 12...	2 57 25·736	2 57 25·308	−16·138	− 1·823	2 57 40·051	2 57 39·623	2 57 39·837	·214
" 13...	2 57 25·446	2 57 25·018	−16·601	− 2·043	2 57 40·004	2 57 39·576	2 57 39·790	·214
" 15...	2 57 23·923	2 57 23·551	−18·588	− 2·529	2 57 39·982	2 57 39·610	2 57 39·796	·186
" 15...	2 57 23·702	2 57 23·343	−18·832	− 2·565	2 57 39·969	2 57 39·610	2 57 39·790	·108
							h m s	
					Mean..........................		2 57 39·802	
					Personal equation............		·122	
					Difference of longitude.......		2 57 39·924	
					Longitude of Ottawa.........		5 02 51·983	
					Longitude of Pouce-Coupé...		8 00 31·907	

AZIMUTH AT COLLINGWOOD

Date	Azimuth of line Collingwood to West Base	Date	Azimuth of line Collingwood to West Base
1917	° ′ ″	1917	° ′ ″
June 14............................	98 49 27·80	June 24..........................	98 49 29·62
" 14............................	98 49 27·89	" 24..........................	98 49 29·22
" 14............................	98 49 30·61	" 24..........................	98 49 30·69
" 20............................	98 49 29·25	" 24..........................	98 49 25·73
" 20............................	98 49 25·54	" 24..........................	98 49 28·54
" 20............................	98 49 23·37	" 24..........................	98 49 30·52
" 20............................	98 49 28·00	" 24..........................	98 49 30·42
" 20............................	98 49 28·03		
" 21............................	98 49 30·67	Mean....................	98 49 28·59
" 21............................	98 49 29·88	Aberration..............	0·32
" 21............................	98 49 29·07		
" 21............................	98 49 27·89	Azimuth of line.........	98 49 28·91
" 21............................	98 49 27·14		
" 21............................	98 49 29·02		
" 21............................	98 49 26·42		
" 21............................	98 49 27·03		
" 21............................	98 49 29·74		

AZIMUTH AT SOUTHWOLD.

Date	Azimuth of line Southwold–Westminster	Date	Azimuth of line Southwold–Westminster
1917	° ′ ″	1917	° ′ ″
July 4............................	40 51 37·05	July 5..........................	40 51 35·49
" 4............................	40 51 39·35	" 5..........................	40 51 36·19
" 4............................	40 51 38·45	" 5..........................	40 51 37·13
" 4............................	40 51 37·56	" 5..........................	40 51 38·28
" 4............................	40 51 37·50	" 5..........................	40 51 37·26
" 4............................	40 51 38·40		
" 4............................	40 51 37·31	Mean....................	40 51 37·39
" 5............................	40 51 35·47	Aberration..............	0·32
" 5............................	40 51 37·79	Corr'n to Geodetic point.	0·68
" 5............................	40 51 37·49		
" 5............................	40 51 36·99	Azimuth of line Southwold to Westminster..	40 51 38·39
" 5............................	40 51 37·98		

Standardization of Tapes.

The invar base line tapes of the Geodetic Survey were standardized in May in preparation for the measuring of the base line on the Pacific Coast.

The methods employed were those described in the report of 1917-18 on "Standards of the Geodetic Survey of Canada". The length of the five metre bar in a solution of ice and water was obtained from the standard nickel bar No. 10239. The length of the reference tape No. 4252 was then determined from the five metre bar, and the length of the other tapes Nos. 13814, 3139, 3140 and 3141 were obtained by comparisons with tape No. 4252. The results of the different operations are given in the following table:—

Length of 1-metre bar No. 10239 at 0° C.	Length of 5-metre bar at 0° C.	Length of Tapes at 16·5° C.				
		No. 4252	No. 13814	No. 3139	No. 3140	No. 3141
Metres 1·0000269	Metres 4·9999532	Metres 50·000577	Metres 50·000478	Metres 49·999678	Metres 50·000220	Metres 50·000593

Owing to the great difficulties encountered, the base on the British Columbia coast was not ready for measurement last season, and the tapes were not used in the field, consequently no further tests were made with them in the fall. Early in the spring of 1919 it is the intention to make a complete set of observations.

In addition to the standardization of the five invar tapes the length of a 264-foot steel tape of the International Boundary Survey was determined.

A base line of length about 725 metres was measured with this four-chain tape and also with the invar tape No. 3141, and the length of the former deduced from the latter.

A table of the lengths of the five invar tapes for the last five years follows:—

Length of 5-metre Bar at 0° C and tapes at 16·5 C from standard nickel Bar 10239.

Date	5-metre bar	Tape 4252	Tape 3139	Tape 3140	Tape 3141	Tape 13814
	metres	metres	metres	metres	metres	metres
1908	4·9999464					
July, 1914	4·9999503	50·000382	49·999525	50·000004	50·000510	50·000067
Dec. 1914	4·9999489	50·000415	49·999593	50·000119	50·000600	50·000118
June, 1915	4·9999507	50·000446	49·999612	50·000154	50·000615	50·000231
Nov. 1915	4·9999432	50·000393	49·999612	50·000142	50·000579	50·000211
May, 1917	4·9999490	50·000604	49·999754	50·000306	50·000730	50·000460
Sept. 1917	4·9999499	50·000569	49·999683	50·000204	50·000618	50·000394
Nov. 1917	....	50·000580	49·999642	50·000221	50·000596	50·000464
May, 1918	4·9999532	50·000577	49·999678	50·000220	50·000593	50·000478

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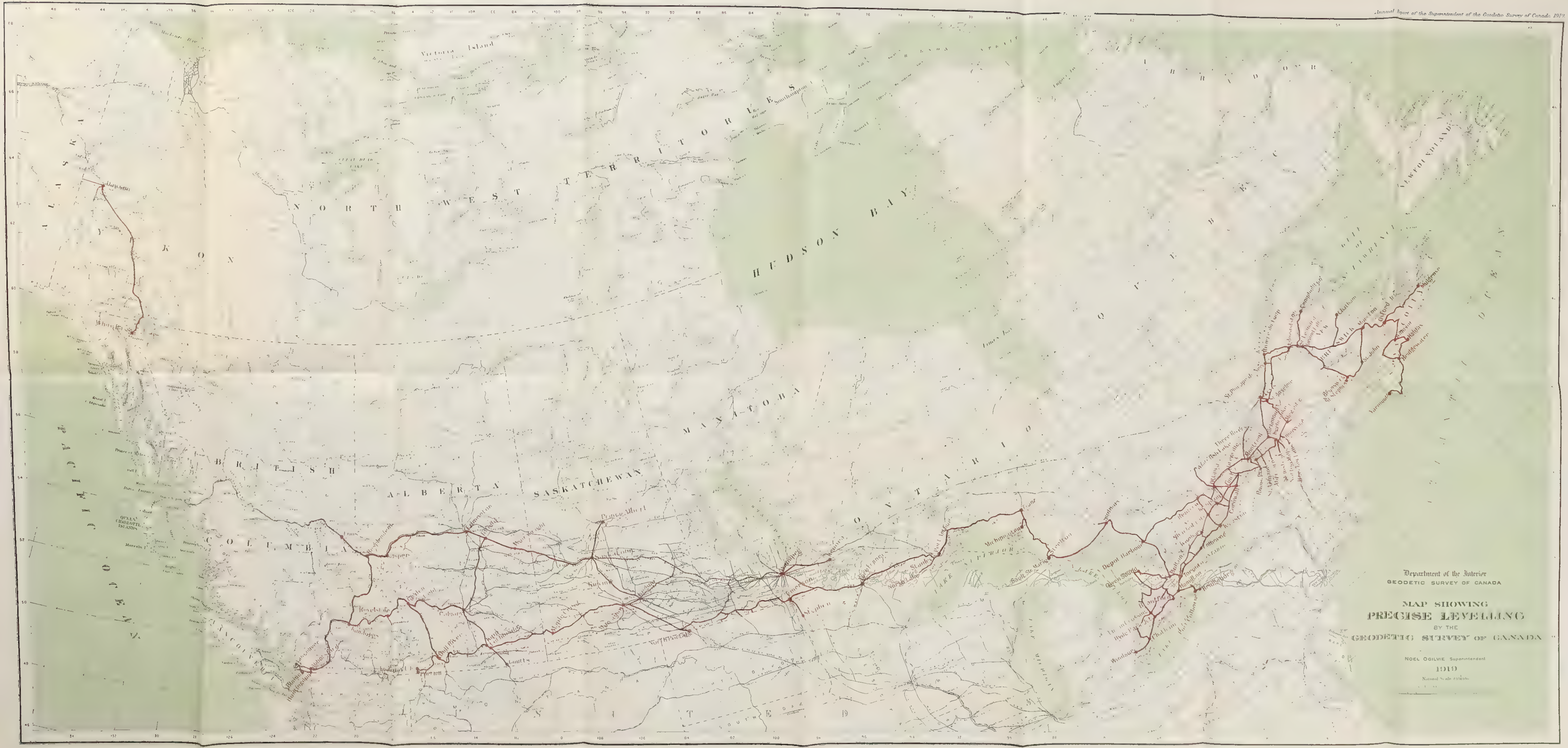
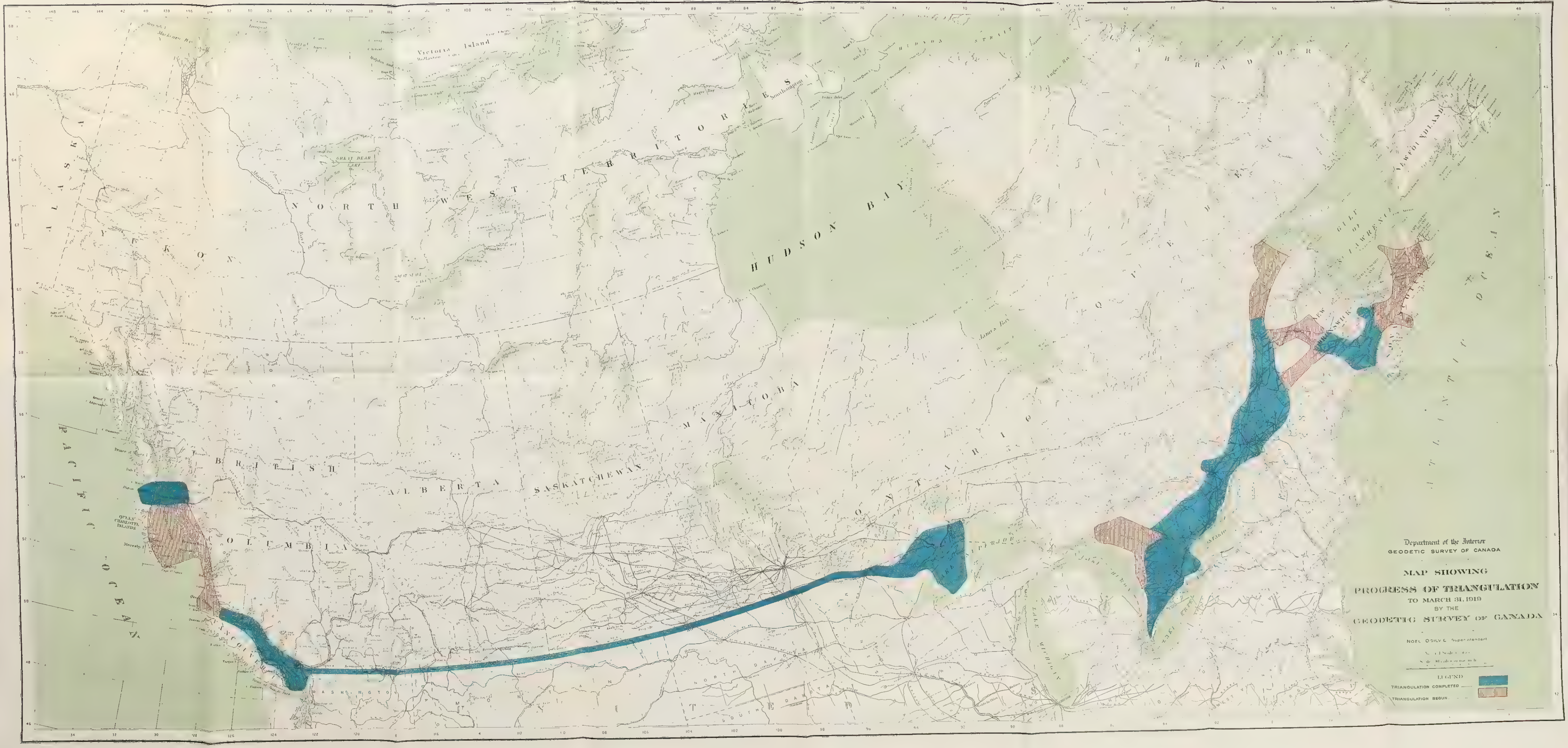


Precise Levelling, Published.
Precise Levelling, Not Published.


Department of the Interior
GEODETIC SURVEY OF CANADA
MAP SHOWING
PROGRESS OF TRIANGULATION
TO MARCH 31, 1919
BY THE
GEODETIC SURVEY OF CANADA
NOEL OGILVIE Superintendent
LEGEND
TRIANGULATION COMPLETED
TRIANGULATION BEGUN
NORTH WEST TERRITORIES
YUKON
ALASKA
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
LABRADOR
NEWFOUNDLAND
HUDSON BAY
James Bay
HUDSON STRAIT
Victoria Island
Southampton
GREAT BEAR LAKE
GULF OF ST LAWRENCE
NEW BRUNSWICK
QUEEN CHARLOTTE ISLANDS
PACIFIC OCEAN
ATLANTIC OCEAN
NORTH DAKOTA
SOUTH DAKOTA
WASHINGTON
MONTANA
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON